Encouraging innovation by means of IT-based cooperation

Working paper

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Abstract
The aim of this research paper is to asses how Information and Communication Technologies (IT) should favor firms' interactions with their environment and make easier their accessibility to innovative networks. Our empirical analysis investigates the effects of IT-based cooperation on the innovation process in a sample of Catalan firms. IT emerges as a key factor driving cooperation and encouraging network economies through the improvement of the existing cooperative networks, but also behaving as a strategic tool to break some firms' obstacles to innovate.

Keywords
innovation process, network firm, IT use, cooperation, absorption capacity

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Introduction

Traditionally, the economic analysis of firms hasidentified the innovation as the introduction of a new good, a new production process, a new organization form, a new supply source, a new market or a new way of doing things[1].

At the present, firm's innovation is understood as an interactive, non linear and complex learning process[2], and knowledge is both its basic resource and its main result. Consequently, the success of the innovation process is closely related to the knowledge management inside the firm, but also to the external support coming from the firm's environment. Usually, the cooperation among firms or with institutions is critical for innovation success especially in the case of small and medium enterprises (SMEs) due to their lower ability to develop the new and diverse knowledge that promotes innovation. Nevertheless, some investigations assert that large firms do not only carry out a bigger innovative effort, but they are also more prone to cooperate technologically for two reasons. Firstly, they can get more gains from collusion, as they internalize different types of externalities more easily. Secondly, because large firms can develop more specialized assets (tangible and intangible) and they are surely more attractive for potential partners.

Therefore, firm's innovation activity is a complex phenomenon. It is fed by tacit and codified or explicit knowledge[3] and it is affected by a wide range of internal factors and by other knowledge sources coming from its environment. Moreover, innovation process is a consequence of both a highly formalized research process and other informal relationships. The innovation process also benefits from both the competence and the cooperation between firms and/or institutions. And this process can lead to radical technological changes and to small incremental improvements of the current set of technologies.

Most of the recent empirical research[4] on the relationship between networks and innovation is focused on formal ties established among organizations and institutions. However, a few studies also link informal ties to the innovative process[5]. All of them show the positive effects of the network structure and the formal and informal ties for the provision of new resources and knowledge and, consequently, the propensity to innovate. As Hansen (1999) points out, complex knowledge is probably most easily diffused by means of tightly knitted networks. These close-knitted kind networks also seem to show a higher ability to transfer tacit knowledge[6] and, therefore, they benefit from strong local ties and frequent interactions.

[1] Schumpeter (1934).
[2] The Kline and Rosenberg's chain-linked model (1986).
[3] Each one with very different properties, as it is pointed in Nonaka & Takeuchi (1995).
[4] Powell (1998), Powell et al. (1999), Ahuja (2000), Baum et al. (2000), Godoe (2000) or Stuart (2000).
[5] Von Hippel (1987), Saxenian (1994), Tsai & Ghoshal (1998) or Cohen & Fields (1999).
[6] As it is suggested in Van Wijk et al (2003).

The aim of this paper is to investigate how this process is affected by the use of the Information and Communication Technologies (IT) on the innovations based on collaboration. To a large extent, the studies on networks and innovation have focused on high technology activities located in specific areas with a very fertile innovative climate and most of them usually use patents as a proxy for innovation[7]. In our research, we analyze IT-based cooperation to innovate in the whole economic activity. To carry out this analysis we use a wide range of measures of innovative output for several reasons. First, in low knowledge intensive industries patents are not the usual[8]. Second, we incorporate the specific effects of the IT-use as a strategic tool to break the economic barriers to innovation based on cooperation. Lastly, we analyze also these technologies as a mean to encourage distant cooperation since they reduce the cost related to the distance and they strength the ability to transfer tacit knowledge beyond local proximity[9].

Data and methodology

The patterns of the adoption and use of new IT are explored from the analysis of 2.038 firms located in Catalonia. The PIC project is the specific research that analyses their IT-use[10]. This sample is representative of the whole economic activity and of all firm's dimensions located in this region.

As the innovation process is a complex phenomenon of a heterogeneous nature, it seems to be necessary to describe the firm's innovative activities through a wide set of indicators. This range of indicators should facilitate us the understanding of the specific patterns of the firm's innovative activity. It should also permit us to identify different innovation types.

[7] Griliches (1990).
[8] Neither they are not frequent in Catalonia.
[9] As it is stated in Vilaseca and Torrent (2004).
[10] The Project Internet Catalonia (PIC) is an interdisciplinary research project about the information society in Catalonia carried out by researchers of the Internet Interdisciplinary Institute (IN3) at the Universitat Oberta de Catalunya (UOC, Open University of Catalonia). PIC is comprised of a series of coordinated research projects which are all under an umbrella project co-directed by professors Manuel Castells and Imma Tubella. Among them, this paper focuses on the results obtained in the research project *Information and communications technologies and transformations in Catalan businesses*. It has the prime objective of analyzing the transformations in business strategies and organization linked to the use of information and communication technologies (ICT). The empirical contrast was carried out through surveying a representative sample of Catalan businesses, using a sample range of 2,038 businesses stratified according to the activity sector and the company size (in terms of number of employees). The field work for the survey took place from January to May 2003, and 2.038 personal interviews to businesspeople and managing directors of each firm were done. The selection of firms was made with a random procedure, with previous fixed marginal quotes. The stratification considered in the research project according to the activity sector was defined and it gave rise to the following 6 groups: Information industry, Low technology industry, Medium technology industry, High technology industry, Less intensive knowledge services, and Intensive knowledge services. Concerning the company size, the survey was designed taking into account the following stratification: 5 or fewer employees, from 6 to 9, from 10 to 19, from 20 to 99, and 100 or more employees. Regarding that the total number of firms in Catalonia is about 515,700, the error margin, with a predefined level of confidence of 95.5%, for the inference analysis derived from de sample results (which were fixed by weighting), is ±2.22 (p=q=50). More concretely, for the analysis of the results according to the company size, the margin of error for the same confidence level is set between 4.20 and 5.46 (in absolute values). In the case of the activity sector stratification, the sample is representative for the level of confidence of 95.5%, with a margin of error that moves, depending on each sector, from 4.82% to 5.67%. For further information about the PIC project, please visit the following web page: http://www.uoc.edu/in3/pic/eng/index.html.

As Arvanitis and Hollenstein (2001) and Hollenstein (2003) suggested, the criteria selection to be applied in defining these different patterns of innovation should be based on two different set of indicators:

- Innovation indicators, representing different aspects of the innovation pattern of firms. Mainly, the input and output sides of innovation, the firm's organization and its intensity of IT use.

- External knowledge sources that a firm could use in its innovative activities, both in an informal way and through formal cooperation agreements.

Innovation types based on these two categories of variables are described by a number of additional relevant variables for the innovation process. These variables identify both the firm's absorption capacity and the knowledge spillovers from its environment. In particular, we include three variables to recognize the internal technological capability of the firm[11]:

- The availability or absence of an R&D Department
- The qualification degree of the labor force[12]
- The labor training[13]

Additionally, we include two complementary variables to identify the knowledge spillovers coming from:

- The cooperation to innovate with other firms and/or institutions
- The consultancy to innovate with specialized professionals or firms

In our analysis we also consider three other determining factors of the firm's innovation process, as the technological progress depends on the actuation of the firms as well[14]:

- The extent of labor flexibility
- A process-oriented organization
- The degree of IT use[15]

[11] As a proxy of the absorption capacity identified in Cohen and Levinthal (1990).
[12] In this case, we consider whether the majority of the labor force has a high education degree or not.
[13] In this case, we consider whether the firm develops a training programme for its labor force or not.
[14] That is, the endogenous source pointed out in Nelson and Winter (1982). In fact, and according to Castells (1996), these three variables represent the characteristics of the network firm.
[15] The scale of this variable ranges from 3 (when IT is used in four or more firm's strategic areas) to 1 (when IT is used only in one or none strategic area).

Furthermore, our model pays attention to the different innovation typologies carried out with IT support, both in an individual way and also in their different combinations. That is[16]:

- Product innovation
- Process innovation
- Organizational innovation

Innovation clusters

A cluster analysis will allow us to identify innovation patterns of several groups of firms. The first step of the factor analysis, shown in detail in table 1, leads to satisfactory results. The five factors extracted in the analysis account for 60% of the total variance. The first factor explains 15% of the total variance and gives high weights to input and output-oriented indicators of product innovations. The second component, accounting for 13% of the variance, refers only to process innovation and it is heavily based on the knowledge generated inside the firm. The third factor, capturing 11,5% of the total variance, shows high loadings in external knowledge sources (mainly, cooperation) and a process-oriented organization. The fourth component is linked to R&D activities (10,5% of the total variance) and to the degree of labor flexibility. Finally, the fifth (9,5%) is related to an IT-intensive organization and the organizational innovation.

Table 1.- Factor Analysis

	Component 1	Component 2	Component 3	Component 4	Component 5
Absorption capacity					
R&D Department	0,057	0,247	0,228	0,562	-0,132
High education degree	0,701	0,070	0,128	0,041	-0,093
Training effort	0,253	0,092	0,266	-0,663	0,027
Knowledge sources					
Cooperation to innovate	0,131	-0,104	0,839	-0,086	0,065
Consulting to innovate	0,089	-0,825	0,033	-0,117	0,053
Innovation typology					
Product innovation	0,738	0,009	-0,097	-0,008	0,100
Process innovation	0,305	0,652	0,149	-0,176	0,110
Organizational innovation	0,274	-0,270	-0,046	0,187	0,661
Organizational change					

[16] In each of these types of innovation we consider that a firm innovates when it has introduced a novelty during the last two years.

Labor flexibility	0,194	-0,110	0,128	0,582	0,190
Process organization	-0,119	0,226	0,681	0,219	-0,095
IT use	-0,190	0,228	0,015	-0,105	0,821
% Variance	15,32%	12,98%	11,52%	10,45%	9,50%
(% accumulated)	15,32%	28,30%	39,82%	50,27%	59,77%

In the second step, we develop a non-hierarchical cluster analysis based on the five principal components extracted in the previous factor analysis. This analysis leads us to group the firms in terms of innovation indicators into five categories. The achieved solution shows satisfactory statistical properties in the relationship of within-cluster distance comparing it to the variance between clusters. We complete this analysis with a set of variables, which offer a general characterization of each group of firms.

Table 2.- Cluster Analysis

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Total Firms
Absorption capacity						
R&D Department	22%	46%	30%	12%	53%	32%
High education degree	6%	17%	69%	14%	50%	28%
Training effort	42%	71%	99%	87%	48%	67%
Knowledge sources						
Cooperation to innovate	14%	93%	71%	10%	13%	36%
Consulting to innovate	74%	48%	46%	16%	20%	42%
Innovation typology						
Product innovation	57%	49%	73%	58%	98%	66%
Process innovation	16%	75%	82%	88%	97%	67%
Organizational innovation	46%	66%	18%	40%	59%	47%
Organizational change						
Labor flexibility	51%	77%	42%	34%	89%	58%
Process organization	13%	65%	64%	12%	25%	32%
IT use (1: low / 3: high)	1,24	1,98	1,05	1,94	1,62	1,56
% Firms	26,20%	17,64%	15,58%	20,55%	20,03%	100,00%

Next, we describe the specific features of each cluster and we also state some general characteristics of the firms of these clusters. The related information is presented in tables 2 and 3. Cluster 1 is the largest in terms of number of firms (26% of our sample). Innovative activities of firms belonging to this cluster are based mainly on the knowledge diffusion from consulting. The results suggest that this cluster is basically composed of micro firms (less than 5 employees), comparing it to the average of the whole economy. We also find a strong relative presence of firms from less technological-intensive industries and a minor presence of foreign capital.

Although cluster 2 comprises only 18% of firms, this rate will be probably much higher in terms of employment because the weight of the medium and large companies of this group is the highest. The relative weight of the low and medium technology activities and the presence of foreign capital are stronger than in the first group. Firms are characterized by a strong absorption capacity, with a dominant role of the R&D department and a strong investment in training the labor force. The innovation process is driven by the knowledge diffusion coming from the cooperation with other firms and/or institutions and from consulting activities.

Therefore, developing a strong absorption capacity seems to affect positively the firm's ability to exploit the opportunities derived from external cooperation. The rate of acquisition of skills and resources from the outside seems to be closely linked to the internal generation of expertise. Besides, the innovation process in these firms is accompanied by an intense organizational change, which has evolved towards a process-oriented organization and, consequently, the outputs of the innovation process lead to changes in production process and also in the organizational structure. Finally, the innovation process in this group of firms is IT-intensive and it is based on labor flexibility.

Cluster 3 is composed by 16% of firms, mainly micro firms (less than 5 employees) of the most knowledge-intensive activities (information industry and services). In this case the innovation process is also driven by cooperation, it is oriented to complex innovations, which imply simultaneously both product and process improvements, and it is related to organizational process. Firms of the information industry are particularly well represented here and knowledge-intensive services to a quite substantial extent as well. Probably, the main aim of IT-based cooperation in this group is a better access to complementary knowledge and essential resources, and a higher credibility to develop new technologies or risk-sharing in environments with high technological uncertainty, as external networks acquire a greater importance during periods of technical discontinuity. In this case, cooperation is obviously carried out among organizations with similar levels of absorption capacity.

Cluster 4 groups almost 21% of the sample of firms. It includes those firms in low knowledge-intensive activities with a strong orientation to process innovations. Although these firms lack of a strong absorption capacity (in terms of R&D department or high-qualified labor force), they

compensate it through an intense effort in improving their human capital skills and a considerable penetration of IT. The innovative activity in this group is probably the result of an incremental and non-formalized process, coming from the efforts of non-specialized labor.

Finally, in cluster 5 we can find the resting 20% of firms. In this case, the output of the innovation process is highly complex and sophisticated because it includes all types of innovation: product, process and organizational. In contrast with the previous cluster, firms' innovation in this group is the result of a systematic and formal process, involving mainly the research department. These firms take profit of the highly skilled labor and they clearly show the highest presence of labor flexibility. This innovation pattern is especially present in services, high technology-intensive manufacturing industries and firms with a higher degree of foreign capital penetration.

Table 3.- General characteristics of firms

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Total Firms
Firm dimension						
Micro	80,4%	69,2%	90,1%	80,0%	79,3%	79,6%
SMEs	19,6%	27,0%	9,9%	19,2%	19,8%	19,4%
Large	0,0%	3,8%	0,0%	0,8%	0,9%	1,0%
Activity						
Information industry	9,2%	9,6%	14,3%	4,1%	9,4%	9,0%
Low-tech industry	11,1%	14,4%	0,0%	11,6%	4,3%	8,7%
Medium-tech industry	3,3%	5,8%	4,4%	3,3%	0,9%	3,4%
High-tech industry	2,6%	5,8%	1,1%	2,5%	4,2%	3,3%
Other service activities	54,9%	48,1%	56,0%	66,1%	65,8%	58,4%
Knowledge-intensive services	18,9%	16,3%	24,2%	12,4%	15,4%	17,2%
Firm control						
Foreign	9,7%	13,6%	11,0%	1,7%	19,0%	10,8%
Domestic	90,3%	86,4%	89,0%	98,3%	81,0%	89,2%

In conclusion, we can identify five different innovation clusters, which are characterized by specific innovation strategies. These innovation types are described by diverse underlying variables that are relevant for the innovation process and that among cluster basically differ in terms of:

- *The direction and complexity of innovation efforts*: product and process innovations in the case of cluster 3; product in cluster 1; process and oorganizational innovations in cluster 2; process in cluster 4 and all kind of innovations in cluster 5.

- *The sources of knowledge*: cooperation to innovate (in clusters 2 and 3); depending on external consulting to develop innovations (in the case of cluster 1) or with a low degree of external knowledge sources (clusters 4 and 5).

- *The degree of absorption capacity*: the type of internal resources used in the innovation process varies among the knowledge creation due to a high innovative effort (cluster 4), the presence of an R&D department (clusters 2 and 5), a high-skilled labor force (cluster 3) or a low absorption capacity (cluster 1).

- *The intensity of the organizational change*: labor flexibility, process organization and medium-high IT use (cluster 2), process organization (cluster 3), medium-high IT use (cluster 4), labor flexibility (cluster 5) or low degree of organizational change (cluster 1).

This analysis also shows how the characteristics of the firms of each cluster differ. In this way, micro firms are highly representative of cluster 3, whereas the innovative process of larger firms is better identified in cluster 2. In most cases, the relationship between industries and clusters is not unequivocal. The majority of industries are distributed to a significant extent in two or three clusters, which could point out a heterogeneous structure of industries in terms of product lines and/or to the existence of a significant degree of freedom for individual firms to choose firm-specific innovation strategies in similar technological and economic environments.

In general, most of the clusters group firms of several industries. However, cluster 5 exhibits a significant presence of firms in services and in high technology-intensive manufacturing industries, cluster 2 seems to be related to manufacturing activities and cluster 3 to information industry and knowledge intensive services. On the other hand, the presence of foreign capital seems to be more important in clusters 2 and 5, which comprise a higher relative presence of large firms and a higher intensity of innovative activities. In general, these clusters are the most active in receiving foreign direct investment.

Therefore, manufacturing and some service activities, with a higher presence of large firms and foreign investment, seem to take over the leadership of the innovative activities in Catalonia. On the other hand, the innovation based on cooperation is not related to a single firm size or to a single economic activity[17], but to different innovation inputs: the presence of an R&D department, a high absorption capacity and a process-oriented organization.

What drives cooperation?

In the previous section, the importance of IT-based cooperation for the innovation process has been proved. Now, we carry out a new factor analysis. The object of this research is to identify

[17] Despite this, it is a bit more frequent in the information industry and in the knowledge-intensive services.

both the typology and the object of the cooperation based on the use of IT. For that, we take in consideration a set of variables related to different characteristics of the cooperation process.

As IT-based cooperation is a significant actor in firm's innovation process, mainly in the case of firms included in clusters 2 and 3, in the second part of this paper, we will develop a new factor analysis for the 355 cooperating firms. Its objective is to identify different ways to cooperate to innovate with IT-use. According to Powell and Grodal (2004), these taxonomies depend on different characteristics based on the cooperation typology and the cooperation object.

On the one hand, the cooperation typology includes a set of variables linked to the specificities of cooperation based on IT-use:

- *value-chain cooperation* (from suppliers to customers),
- *scientific cooperation* (with universities or specific research institutions),
- *horizontal cooperation* (with competitors or other firms of the same industry),
- *local cooperation* (in the same region),
- *new cooperation* (first-time cooperation to develop innovations).

On the other hand, the cooperation object includes a set of variables related to diverse expected outcomes of innovation:

- Decreasing the cost of radical innovations: *new product/service* (for innovative firm), *new process* (radical transformation based on IT-use) and *new organization* (new market-oriented organizational structures).
- Encouraging the interdependence of the innovation process: *very-innovative firms* (product and process innovations based on IT-use) and *highly-innovative firms* (product, process and organizational innovations based on IT-use).
- Developing new and more sophisticated competitive strategies based on flexibility, market-niches or customer-proximity: *competitiveness strategy* (product differentiation, flexibility and quick-response).
- Risk-sharing; that is, to reduce commercial or technological uncertainty related to the development of new technological standards (*techno complexity*), the creation of new business channels (*innovation object*) or the exploitation of higher markets (*export oriented*).

Table 4.- Factor Analysis

	Component 1	Component 2	Component 3	Component 4	Component 5
Cooperation typology					
Value-chain cooperation	-0,105	0,138	-0,800	0,102	-0,091
Scientific cooperation	0,267	-0,396	0,552	0,216	-0,286
Horizontal cooperation	0,061	0,501	-0,057	0,074	-0,218
Local cooperation	-0,194	0,215	0,677	0,023	0,006
New cooperation	-0,001	-0,016	-0,004	0,242	0,844
Cooperation object					
Very-innovative firms	0,787	0,140	0,155	0,040	0,100
Highly-innovative firms	0,855	-0,080	-0,160	0,082	-0,188
New product/service	0,321	-0,481	0,091	-0,427	0,487
New process	0,489	0,002	-0,271	0,121	0,193
New organization	-0,024	0,802	0,125	-0,024	0,094
Competitiveness strategy	0,236	0,477	-0,318	0,035	0,299
Techno complexity	0,141	0,024	0,010	0,766	-0,082
Innovation object	0,259	-0,278	-0,212	0,637	0,293
Export oriented	-0,057	0,229	0,086	0,582	0,276
% Variance	16,57%	13,61%	11,54%	10,26%	8,18%
(% accumulated)	16,57%	30,18%	41,71%	51,97%	60,16%

This process should favor the association of several groups of firms based on their cooperation activity. The first step of the factor analysis, shown in detail in Table 4, leads to statistically satisfactory results: the five factors extracted in the analysis account for 60% of the total variance. The fist factor gathers 17% of the total variance and it is related to the IT-based cooperation oriented to the development of more complex innovations. The second component reflects 14% of the variance and it is linked to the cooperation to implement new organizational structures. The third component explains 12% of the variance and it refers to the cooperation with the local scientific institutions. The fourth factor, which accounts for 10% of the variance, is related both to the cooperation to develop new competitive advantages and to the rupture of the firm's technological frontier. Finally, an additional 8% of the variance is explained by the fifth component, associated to the ability of IT to break some barriers to innovation through an easier cooperation.

Cooperation clusters

Firms were grouped in four different categories using cluster analysis. The result shows satisfactory statistical properties in terms of the relationship of within-cluster variance compared to the variance between clusters.

The results obtained are included in table 5. Almost 30% of the sample belongs to cluster 1. In this group the innovative activity is sustained by cooperative links with competitors and local scientific institutions. The main objective of such cooperative agreements is to introduce new products in the market.

The second cluster contains only 11% of firms. In this case, IT-use has become a useful tool to break the barriers to cooperate. The interaction in this group is carried out with all the accessible knowledge sources, even those located outside. Therefore, IT-based cooperation is mainly developed along the value-chain, but also with the scientific pool, as well as taking profit of the information obtained from competitors. The objective of this kind of cooperation seems to be risk-sharing and it is oriented to develop radical innovations in terms of new products, new processes and new organizational structures, which lead to a higher technological complexity and the generation of new sources of competitiveness. As stated in Powell et al. (1999) and in Baum et al. (2000), the diversity of network ties and the variety of knowledge and capabilities seem to influence positively the rates of innovation. Probably, the greater ability to cooperate with diverse types of institutions or organizations permits firms of this cluster to maintain their leadership position in the industry.

The concern for the improvement of competitive performance is also a priority for a few firms included in cluster 3. However, in this case, the IT-use is a strategy oriented both to encourage the first-time cooperation with suppliers and customers, proximately located, to incorporate more sophisticated technologies, and to improve their products' portfolio. Although firms in this group make a considerable use of technological advances, they do not seem to be science-driven. The development of IT-based cooperation along the value chain facilitates knowledge sharing among firms, a common learning process and organizational culture and also a faster responsiveness to market demands. All of them encourage innovation and the development of more complex competitive strategies.

Table 5.- Cooperation indicators

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total Firms
Cooperation typology					
Value-chain cooperation	43%	99%	100%	96%	81%
Scientific cooperation	44%	36%	6%	17%	27%
Horizontal cooperation	27%	31%	2%	13%	19%
Local cooperation	98%	18%	96%	60%	68%
New cooperation	54%	86%	96%	24%	42%
Cooperation object					
Very-innovative firms	69%	71%	99%	23%	44%
Highly-innovative firms	21%	65%	1%	13%	21%
New product/service	91%	99%	12%	29%	55%
New process	1%	34%	0%	0%	4%
New organization	10%	42%	0%	15%	16%
Competitiveness strategy	51%	69%	94%	57%	58%
Techno complexity	15%	60%	93%	34%	33%
Innovation object	14%	92%	95%	15%	26%
Export oriented	0%	1%	93%	0%	3%
% Firms	29,86%	10,99%	3,38%	55,77%	100,00%

Finally, cluster 4 includes most of the cooperative firms (almost 56%). For these firms, cooperation is a usual practice, mostly it has a local scope, it is based on the interaction through the value-chain and it seems to be oriented preferably to the development of incremental innovations. Probably, this group includes dense and old network links among organizations, but it seems to be limited to be up to date in technological fields. The large number of firms in this cluster reveals an unsatisfactory exploitation of the competitive advantages based on cooperation. This shortage is critical when micro firms are prevalent, as in Catalonia, because innovation process for this type of firms is highly dependent on the knowledge diffusion and the quality of the interactions with their environment.

This result could suggest some kind of a learning-cycle process, since the relevance and the returns of new cooperation could overcome the benefits of the existing cooperation when the IT-use is not accompanied by organizational innovations. Assuming the innovation types before described, we could also look for different innovation modes. In fact, from the addition of diverse innovation inputs to the cooperation clusters previously identified, we notice that there are clear

differences of high relevance for the innovative activity between clusters. Starting from Hollenstein's (2001) methodology, we could identify these four different cooperation modes:

- Science-based and domestic-oriented product innovators (cluster 1): Firm's innovation is mainly oriented towards the development of new products for the domestic market and it benefits from local external knowledge sources. Basically, innovations are science-related and based on firm's high qualified staff, but the disposal of an R&D department does not seem to be essential.

- Fully-network-integrated firms (cluster 2): In this case, firms' innovation process benefits from large amounts of R+D, a high qualified staff and an intensive use of all kind of external knowledge sources. Cooperation probably has an institutionalized feature, it is developed also with foreign partners and it is oriented to develop radical innovations with a high IT content.

- Export-oriented incremental innovators with strong external links along the value-chain (cluster 3): Firms benefit from favorable market perspectives but they do not dispose of very positive supply-side conditions for the generation of innovations. Consequently, both product and process innovations are incremental in nature and heavily based on cooperation along the value chain. The innovative activity of these firms is strongly market and export-oriented as well as the IT-based cooperation encourages the development of new technological standards.

- Low-profile innovators without strong external network (cluster 4): In this case, the development of innovations has an incremental nature and both process and organizational innovations are quite marginal. Even so, both demand and supply determining factors of innovation are not very unfavorable. The use of external knowledge sources is poor and it is highly concentrated on suppliers and customers.

Table 6.- Innovation inputs

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total Firms
R+D+I Department	27,4%	62,5%	8,3%	21,7%	27,5%
High education degree	38,6%	35,9%	8,3%	36,2%	35,9%
Process organization	49,1%	38,5%	8,3%	44,7%	44,1%
ICT use	1,38	1,92	1,09	1,35	1,42

Innovation based on cooperation

In the last section of our empirical analysis we exploit the qualitative information of IT-based cooperation activities and relate these outputs to input factors of innovation. Later, we translate these qualitative assessments into indicators to study the changes in the propensity to cooperate rather than the degree of cooperation. And, according to Powell and Grodal (2004), as the impact of cooperation on innovation is probably related to both the type of partners and the pattern of previous collaborative relationships, we look for the answers of two research topics:

- On the one hand, we expect to identify the main features of each typology of IT-based cooperation oriented to innovation.

- On the other hand, we expect to ratify the significance of those innovation inputs identified as crucial for cooperation in the innovation clusters analysis developed in first section. That is, the presence of an R&D department, the firm's absorption capacity and a process-oriented organization.

For that, we relate the cooperation characteristics with the change in inputs of innovation, as it was suggested in Licht & Moch (1999). Thus, our empirical model is given by:

$$C^k_i = \alpha^k R_i + \beta^k H_i + \lambda^k T_i + \delta^k L_i + \eta^k P_i + \gamma^k IT_i + \varepsilon_i$$

Where, for each *i* firm and *k* cooperation output:

C^k_i : Cooperation output.
R_i : R&D Department.
H_i : The majority of labor force has a high degree in education.
T_i : Firm develops a training programme for its labor force.
L_i : Firm develops labor flexibility programs.
P_i : Firm's organization is process-oriented.
IT_i : Degree of IT-use in firm's strategic areas.

Given the qualitative nature of the output dimension, we use ordered logit models. The results are reported in table 7, where each row represents a logit regression. Items are grouped according to their association with the different dimensions of the cooperation outputs.

Regarding the different types of cooperation, we corroborate the significance of a strong firm's absorption capacity in terms of the availability of an R&D department, a high-skilled staff and an active labor-training programme. Likewise, the process-organization also seems to help IT-based

cooperation. However, the breaking up of cooperation among different typologies allows identifying different responsibilities among those innovation inputs and the rest.

On the one hand, cooperation on innovation seems to require mainly the presence of high-skilled labor. It is also favored by labor-training programmes in the case of collaborative agreements with other firms and, especially, when cooperating with the general scientific and technological knowledge pool. On the other hand, firms with an R&D department are not always the most active in the innovation based on cooperation. This result is consistent with the higher dependence of SMEs' innovation process on knowledge spillovers, due to their lower absorption capacity[18]. In the case of these firms, most of their collaboration on innovation is not usually based on formal ties, although an R&D department and a high-skilled staff are crucial for the first-time cooperation. Moreover, the strategic use of IT in most of the firm's functional areas seems to be very relevant. Those firms who internalize the IT-use as a strategic tool for their performance are the more inclined to cooperate with the support of IT.

In terms of the cooperation object, the separated analysis according to the different expected outcomes of innovation is useful for our intentions. The results indicate that the absorption capacity, both in terms of an R&D department and a high-skilled staff, is critical for the cooperation oriented to reduce the technological uncertainty. Finally, the effects of IT-use for cooperation are also very significant in the development of innovations destined to create new business channels or new market-oriented organizational structures, whereas the development of radical innovations through IT-based cooperation is connected to flexible and trained teams and it benefits from a process-oriented organization.

[18] In our sample, the presence of a formal R&D department is much more relevant in large firms (66,7%) than in micro firms (14,9%).

Table 7.- Logit Analysis

	R&D Department	High education degree	Training Effort	Labor Flexibility	Process organization	IT Use	R2-Adj.	Number of observations
Value-chain cooperation	1,142	2,740	0,589	1,331	0,800	1,949	0,942	314
	0,711	*0,009*	*0,187*	*0,377*	*0,519*	*0,031*		
Scientific cooperation	1,141	1,812	0,632	0,251	2,104	4,573	0,866	314
	0,672	*0,058*	*0,202*	*0,000*	*0,021*	*0,000*		
Horizontal cooperation	1,584	4,362	3,780	0,574	0,342	1,714	0,869	338
	0,175	*0,000*	*0,001*	*0,089*	*0,001*	*0,048*		
Local cooperation	0,794	1,569	0,616	0,175	1,590	0,397	0,830	339
	0,440	*0,134*	*0,142*	*0,000*	*0,136*	*0,000*		
New cooperation	1,853	0,293	1,827	2,857	0,315	1,263	0,867	338
	0,031	*0,000*	*0,043*	*0,000*	*0,000*	*0,309*		
Very-innovative firms	1,908	1,120	10,777	0,355	0,355	3,144	0,798	337
	0,032	*0,693*	*0,000*	*0,000*	*0,000*	*0,000*		
Highly-innovative firms	1,058	0,184	2,431	0,379	0,652	5,824	0,761	338
	0,883	*0,000*	*0,024*	*0,007*	*0,237*	*0,000*		
International Competitiveness	1,982	0,210	396,302	0,210	0,056	0,361	0,651	329
	0,512	*0,221*	*0,254*	*0,088*	*0,009*	*0,141*		
Export orientation	2,239	0,506	1,811	0,964	0,675	1,122	0,954	336
	0,003	*0,009*	*0,039*	*0,886*	*0,145*	*0,605*		

Innovation object	1,596	0,561	1,391	0,863	0,631	3,691	0,873	338
	0,136	*0,079*	*0,319*	*0,635*	*0,148*	*0,000*		
Techno complexity	1,804	1,828	0,642	0,270	0,306	1,546	0,901	338
	0,044	*0,034*	*0,132*	*0,000*	*0,000*	*0,064*		
New product/service	1,193	0,862	3,158	3,288	0,673	1,193	0,913	337
	0,523	*0,578*	*0,000*	*0,000*	*0,159*	*0,437*		
New process	0,942	0,086	24,819	3,289	0,153	1,812	0,733	338
	0,934	*0,017*	*0,008*	*0,073*	*0,010*	*0,211*		
New organization	0,572	2,088	0,266	2,108	2,718	2,177	0,916	339
	0,133	*0,035*	*0,001*	*0,048*	*0,013*	*0,009*		

p-values are given below the regression coefficients.

Conclusions

A firm does not innovate on isolation, but its innovation process depends on interaction with its environment. Since external networks should assume a greater role during periods of fast technological change, as IT-use moves forward, it could be predictable a higher degree of innovations sustained on cooperation. Have IT affected firm's use of external sources of knowledge? Certainly, IT-based cooperation has revealed as a worthy and strategic tool to encourage innovation in firms because it breaks some economic barriers to cooperate and it favors a more efficient cooperation as well.

In a first step, with a cluster analysis of Catalan firms, we have identified specific patterns of the innovation activities as well as of the exploitation of external knowledge sources. The results show us five different innovation modes. In two of them IT-based cooperation appears as a critical factor. In fact, 36% of firms have supported their innovation process on external cooperation. In those clusters, IT-based cooperation is related, in one case, to a strong absorption capacity and an intense organizational change and, in the other, to the development of knowledge-intensive products or services. Therefore, firm's ability to exploit the opportunities derived from external cooperation to acquire skills and resources seems to be closely linked to the internal generation of expertise and to the development of a process-oriented organization. Furthermore, since the relationship between specific industries and innovation modes is weak, it seems to be a significant degree of freedom to select firm-specific innovation strategies in similar technological and economic environments.

In the next step, from a second cluster analysis based on the cooperation typology and the object of cooperation, we can discriminate cooperative firms into four different cooperation modes: science-based and domestic-oriented product innovators, fully-network-integrated firms, export-oriented incremental innovators with strong external links along the value-chain and low-profile innovators without strong external networks.

Finally, we have connected cooperation typologies and objects with innovation inputs. The results show the different characteristics of each IT-based cooperation type. Such as the organized R&D activity is not the only source of innovation, an R&D department is not always the determining factor of cooperation. However, its presence accompanied with a high-skilled staff is decisive for both the first-time cooperation and the risk-sharing cooperation. This result has clear implications for the research policy in regions with a high density of SMEs. As it was expected, labor skills and training programmes are also crucial in science-based cooperation and, in general, network firms are more inclined to IT-based cooperation, especially when it is oriented to develop new business channels or radical innovations.

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