Cooperative R&D depending on partners' geographical location

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Key words: services R&D, Innovative cooperation, Externalities, Innovative productivity.

Abstract

Using data from the Spanish Survey of Technological Innovation, the paper analyzes differences between services and manufacturing regarding the impact of R&D cooperation on firms' innovative productivity, depending on the geographical location of the partners. Additionally, it examines differences between the services´ categories of the Miozzi and Soete (2001) taxonomy. Results indicate that industrial innovative activity mostly depends on R&D investments, while innovative cooperation is crucial for services. Services innovation benefits mainly from cooperation with international partners, while local cooperation is more effective for manufacturing. In relation to the different services' categories, intensive scale and information services show similar patterns to those of manufacturing.

1. Introduction

Traditionally, innovation analysis has been dominated by paradigms based on manufacturing (Gallouj & Weinstein, 1997). At the most, services were seen as facilitators, imitators or users of innovations. It was considered that services were lagged behind in innovation (Miles, 1993); therefore, they did not have the deserved recognition in the study of economics of innovation. Recently, this perception has changed and now it is a well-known fact that services play an active role in the innovative process of the economy (Howells, 2000; Tether, 2004). Moreover, within this process, services have become key players in the innovative development of the whole system.

The recognition of services as sources of innovation led to the analysis of their differences with the industry. Three main differences have been highlighted (Howells, 2000): (a) the use of different methods of intellectual property to protect innovation, (b) the lesser importance of economies of scale in service innovation, and finally (c) , the fact that, while industrial innovation is grounded on R&D investments, innovation in services is based on external sources. This last difference does not refer that services acquire technology produced by other firms[1]; it means that services' innovative activity benefits from cooperation with external sources of knowledge. This is because innovation in services is characterized by intangibility and interactivity (Tether, 2004). Although innovation in services depends on the interactions between firms working in networks and industrial innovation is based on firms' internal capabilities (Roper & Hewitt-Dundas, 2004; Howells & Tether, 2004), we should not think that services and manufacturing have two different modes of innovation. Actually, there are many forms of innovation and, simply, some of them are more common and/or effective in one sector than in others (Roper & Hewitt-Dundas, 2004). What it is appropriate is to consider the economy as a large and complex set of interrelated functions, in order to analyze innovation as a distributed process between firms and organizations working together in networks (Freeman, 1991). In this context, service and industrial firms are seen as innovative partners. The real challenge is to identify differences and similarities between these two.

This paper examines several factors that influence the innovative productivity[2] of the manufacturing and services with the purpose of comparison. Additionally, it analyzes differences between the different services' categories of the classification of Miozzi and Soete (2001). The analysis focuses on innovative cooperation that firms establish with local and international partners. Therefore, the study estimates the effect of innovative cooperation, depending on partners' geographical location, on firms' innovative productivity. The rest of the study is organized as follows: section 2 reviews the literature and presents the hypotheses on the effects of technological cooperation depending on the geographical location of the partners. The analysis focuses on the differences between service and manufacturing firms. Section 3 presents the data, the sample, the econometric specifications, describes the variables used in the model, and presents a series of descriptive statistics. Section 4 discusses the results. And finally, section 5 presents the main conclusions.

2. Literature review and hypothesis

2.1. R&D cooperation and investment

As has been shown, one of the main differences between the innovative activity of services and the industry is that the first one is based on external sources of knowledge, while the second is based on investment in R&D (Howells, 2000, Roper & Hewitt-Dundas, 2004; Howells & Tether, 2004). Empirical studies show that innovative effort[3] is the most influential variable on manufacturing innovative performance (Belderbos, Carree et al. 2004; Vega-Jurado, Gutiérrez-García et al., 2009). In many industries the majority of the innovative effort is not only made by the firms, but it also developed within them (Nelson, 2000); moreover R&D cooperation has high failure rates in the industry (Harrigan, 1986). However in the case of services, the external sources of knowledge are more important than the innovative effort (Howells, 2000; Tether, 2004). This is due to several reasons: first, innovation in services is continuous and firms adapt themselves while responding to changes in consumer preferences, which requires constant contact with suppliers, customers and competitors. Secondly, innovation in services needs industrial innovations, as many services are provided by the existence of physical goods (hence services cooperate with suppliers to produce innovations). Finally, innovation in services has a more creative character than in manufacturing and creativity is strengthened by the interaction between people from different backgrounds. In general, the characteristics of innovative knowledge that is employed by services require more interactions with external partners. Consequently, the following hypothesis is proposed:

Hypothesis 1: *R&D cooperation causes a greater impact on services' innovative productivity than R&D intensity, while R&D intensity is the major determinant of manufacturing innovative productivity.*

2.2. Local and international R&D cooperation

The type of partner is a key variable determining the effects of R&D cooperation

(Belderbos, Carree et al., 2004; Vega-Jurado, Gutiérrez-García et al., 2009). As anticipated in the introduction, this study is intended to analyze the effect of cooperation based on partners' geographical location, and it differentiates between local partners (located in Spain[4]) and international partners (located outside of Spain).

It is considered that local cooperation is more effective than international because geographical and cultural proximity facilitates networking and the transmission of new knowledge (Fagerberg, 1995, Feldman, 1996), especially when it comes to pass on tacit knowledge that cannot be easily codified (Powell, Koput et al., 1996). In addition, proximity creates economies of scale (Audretsch & Feldman, 1994), facilitates the learning process (Belussi, 1999), reduces uncertainty and opportunism (Williamson, 1985), and proximity is associated with lower research costs for organizations operating in networks (Lorenzoni & Lipparini, 1999). As noted by Eccles and Nohria (1992), an effective interaction requires strong relationships through personal contacts.

However, R&D cooperation with international partners requires greater investments in communication and transportation. Moreover, the different institutional conditions of each country (for example, different appropriation regimes) increase the risk of undesired externalities (Hamel, 1991). In addition, international cooperation is associated with lower levels of trust between partners (Szulanski, 1996), because cultural differences limit the possibilities of share values and objectives that are necessary to facilitate exchange of resources and knowledge (Parkhe, 1991). All these factors reduce the effectiveness of international collaboration (Barkema et al., 1996, Kumar and Nti, 1998, Lane and Lubatkin, 1998). However, the technology needed to maintain global competitiveness is often dispersed throughout the world and firms may require resources that are not available in their home country (Dunning, 1988). In fact, to firms, the main motivation to establish contact with partners in other countries is finding the specific advantages of each zone (Hagedoorn, 1993; Kuemmerle, 1999, Le Bas & Sierra, 2002; Narula, 2002). Resources offered by international partners can stimulate the innovative activity of a firm, supplying new solutions and capabilities (Levinthal & March, 1993). International relations can extend the benefits of cooperation in R&D with local partners and strengthen the firm's competitive advantage in foreign markets. Therefore, international cooperation could provide more flexibility, responsibility, ability to adapt to the conditions of the global markets and reduce risk and uncertainty (Eisenhardt & Schoonhoven, 1996, Hagedoorn, 1993, Kogut & Kulatilaka, 1993, Powell et al., 1996). In addition, communication technologies and a greater economic integration facilitate the establishment of these relationships.

There is only empirical evidence on the effectiveness of international cooperation for manufacturing firms. It has been shown that international cooperation increases productivity growth (Cincera et al., 2003; Lööf, 2008), the number of patents and sales of new products (Miotti & Sachwald, 2003). Nevertheless, several studies have found that international cooperation generates lower yields than local cooperation (Osborn & Baughn,1990, Barkema & Vermeulen, 1997, Inkpen & Beamish, 1997, Das et al., 1998; Makino & Beamish, 1998, Reuer & Leiblein, 2000). However these findings could be the result of analyzing only manufacturing firms.

Several reasons indicate that, in the case of services, international cooperation is more effective than local cooperation. First, having access to various sources of knowledge is more important for services than for manufacturing and innovative knowledge is usually dispersed through the world. Second, given the adaptive nature of services' innovation, global service firms need to be linked with their international clients and suppliers. Third, the intangible component of services' innovation makes personal contact less necessary. Moreover, services are the largest users of ICTs that besides being used as a creative and innovative way (Barras, 1986; Sirilli & Evangelista, 1998; Howells & Tether, 2004) constitute a very suitable method for transmitting knowledge through long distances. Therefore hypothesis two considers the following:

Hypothesis 2. *Services benefit more from international cooperation, while manufacturing from local cooperation.*

Data indicates that firms when participating in innovative partnerships do not need to choose between local or international partners, they can cooperate with both partners simultaneously. It is possible that the fact of cooperating in joint R&D projects, both outside and within national borders, increase the innovative potential of the firm, since the firm is able to access more information (Duysters & Lokshin, 2007). On the other hand, could happened that the higher costs resulting from having to coordinate partners located in different geographical areas or from participating in various projects with different objectives may reduce the innovative performance (Belderbos, Carree et al., 2006). Nevertheless, as firms face greater innovative possibilities when they cooperate outside and within their national borders, the following hypothesis is considered:

Hypothesis 3. *Services and manufacturing cooperating both with local and international partners present a higher innovative productivity than firms cooperating with only one type of partner.*

2.3. Services Sectoral Classification

Miozzi and Soete (2001) propose taxonomy for services, based on the sectoral classification of Pavitt (1984), in which there are three patterns of services' innovation based on their technological regime: (1) supplier-dominated, (2) scale intensive physical networks and information networks, and (3) science-based and specialized suppliers. Appendix 1 shows the activities that are included in each category.

Innovative activities differ at the sectoral level, as each sector has its particular technological opportunities and conditions of appropriation, which determine the technological regime (Nelson & Winter, 1982). Technological regime characteristics influence the effectiveness of technological cooperation and R&D investments. Investment in R&D is preferred when innovative tasks are highly standardized (Mowery, 1983; Veugelers & Cassiman, 1999), since they are associated with low uncertainty and it is unlikely that they involve specific assets; while technological cooperation, by allowing the distribution of costs and risks, it is better when innovative projects are complex, uncertain and involve specific assets. High technology is characterized by a rapid renovation of knowledge and its high degree of complexity, which requires a continuous effort in research and a strong technological foundation (Molero & Hidalgo, 2003). Innovative projects developed by software firms, technical services or engineering services (science-based and specialized supplier services) are much more complex than the innovative activities of firms that develop more traditional services such as hospitality (supplier-dominated services), transport or financial intermediation (scale and information intensive services). Science-based and specialized supplier services should obtain higher yields from cooperation than supplier-dominated and scale and information intensive services. Consequently, we propose the following hypothesis:

Hypothesis 4: *R&D cooperation influences more in the innovative productivity of science-based and specialized supplier services than in that of the supplier-dominated and scale and information intensive services.*

3. Data, empirical model, variables and descriptive statistics

3.1. Data: Spanish Survey of Technological Innovation (PITEC)

PITEC data panel, in general terms, is equivalent to the "Community Innovation Surveys" (CIS) and is accessible via Internet[5]. PITEC is a panel data of a representative sample of firms from all sectors of the economy, allowing making repeated observations over time as well to consider lags when determining the impact of innovative activities. Currently data is available from 2003 to 2009[6]. PITEC includes data from more than 12,800 firms, however, not all these firms have been surveyed every year, given that year after year firms are added and subtracted from the sample.

This study focuses on private manufacturing and service firms, thus excluding all public enterprises, research associations and firms belonging to the following activities according to NACE-93[7] classification: agriculture, petroleum refining and production and distribution of electricity, gas and water. Moreover, because they may lead to distortions in the interpretation of the results, I eliminate all firms that have a number of employees or a turnover equal to zero[8], and those firms that are newly created, or which its sales has increased by at least 10% due to the merger with another firm or whose turnover has been reduced by at least 10% as a result of the sale or closure of the firm[9]. Following Lööf (2007), we also eliminate all those firms which have an R&D outlay that doubles its turnover. The exclusion of these firms is intended to eliminate the influence of the most extreme cases. Furthermore, this study focuses on innovative firms[10], which are the only ones that answer all the questions from the questionnaire, including questions about innovative cooperation. PITEC considers that a firm is innovative if it has introduced a process or product/service innovation, or has abandoned or ongoing innovative activities. After the above restrictions, we have a total of 3,578 services firms, and 5,706 manufacturing firms, evaluated from 2004 to 2008[11], so the number of observations is 10,006 for services and 17,924 in the case of manufacturing. Appendix 1 shows the number of innovative firms differentiating by type of activity.

3.2. The empirical model and methodological aspects

Model (1) determines firms' innovative productivity as a function of technological cooperation, depending on the geographical location of the partners (*intragroup, local, international* and *local&international*), along with other control variables[12]:

$$\log(1+\frac{Innovative\ sales}{Employees})_{i,j} = \alpha + \beta_1 LocalCoop_{i,(t-1)} + \beta_2 InternationalCoop_{i,(t-1)} + \beta_3 Local\ \&InternationalCoop_{i,(t-1)} + \beta_4 Intragroup_{i,(t-1)} + \beta_5 Spillovers_{i,t} + \beta_6 R\&D_{i,(t-1)} + \beta_7 Isize_{i,(t-1)} + \beta_8 demand_{i,(t-1)} + \beta_9 costs_{i,(t-1)} + \beta_{10} Foreign_i + \beta_{11} Global_i + \beta_{12} innovativeproductivity_{t-1} + \gamma \sum Sector_i + \varepsilon_i \qquad (1)$$

Given that innovative productivity is a measure of the sales of innovative products/services new to the market, it behaves as a censored variable which is observable only for a certain group of individuals: firms that have introduced innovations new to the market. The appropriate model to explain these types of variables is the Tobit model (Tobin, 1958). Additionally, to take in account the possible unobserved heterogeneity, the Tobit model of random effects is employed. Random effects model is more appropriate than the fixed effects model because the sample contains data from a large population of firms. Estimators calculated with fixed effects may be less efficient for panels with few periods of time, which does not occur in the random effects model (Heckman 1981). In addition, the fixed effects model cannot include independent covariates with time.

Finally, the study of the effects of innovative cooperation must take into account a possible endogenous relationship between R&D cooperation and innovative output since cooperation improves innovative results, but also those more innovative firms may be more likely to cooperate, because, among other things, are seen as more attractive partners (Tether, 2002). Consequently, the vast majority of studies analyzing the effects of cooperative R&D use lagged independent variables with the intention of analyzing the true effect of cooperation, since R&D cooperation activities do not show results in the same year in which the arrangement is developed. In consequence, independent variables are lagged a period.

3.3. The variables

The dependent variable is firms' innovative productivity which is calculated with the logarithm of 1+ sales of innovative products new to the market, divided by the number of employees of the firm[13]. By estimating innovative performance, instead of total economic performance, we do not need to take into account other factors that affect the heterogeneity of economic performance but not the heterogeneity of innovative performance (Belderbos, Carree et al., 2004). Several studies use this variable o its variation rate as indicator of the firms' innovative performance (Klomp & van Leeuwen, 2001; Lööf & Heshmati, 2002; Belderbos, Carree et al., 2004; Lööf & Broström, 2005; Duysters & Lokshin, 2007). Innovative productivity measures, unlike innovative effort variables, have the advantage of being associated with tangible innovative results (Mansfield, 1984).

Sales of innovations new to the market have been selected, rather than sales of innovations new to the firm or total innovation sales, because innovative cooperation usually pursues the generation of completely new products and services, since these innovations usually involve a greater need for complementary resources and skills (Fritsch & Lukas, 2001). Additionally, the innovative productivity lagged one period (*innovative productivity*) is included in the model as an explanatory variable in order to analyze dynamics in the innovation process. In this aspect, Cefis and Ciccarelli (2005) found that persistent innovators have benefits that are and remain higher than those of firms that are not persistent innovators.

The rest of the variables in the model are: firms' size (*lsize*); R&D intensity[14], which includes both internal and external innovation expenditures; the *demand* and *costs* variables which determine the orientation of innovative efforts towards the generation of new products/services or towards the reduction of costs; the variable *Foreign* which differentiates between national and foreign firms; the variable *Global* which distinguishes between exporters and non-exporters; and finally, a series of dummy variables that indicate to what industry or service the company belongs (*Sector*) [15]. Appendix 2 contains the definition of all the variables and Appendix 3 shows the correlation tables for services and manufacturing.

Furthermore, the independent variables of major interest are those related to innovative cooperation, that the questionnaire defines as innovative activities developed with other firms or institutions in which it is not necessary that the two parts obtain profits. In PITEC, firms provide information on the type of partner and its geographical location. This paper considers the following types of partners: intragroup, suppliers, clients, competitors, universities, technological centers and research institutes, and it takes into account the following categories of geographical areas: Spain, Europe, US and other countries. The model differentiates between four dichotomous cooperation variables: intragroup cooperation (*intragroup*) which takes value 1 if the firm cooperates with the firms of its group, cooperation with local partners (*LocalCoop*) which takes value 1 if the firm cooperates exclusively with partners located in Spain, international cooperation (*InternationalCoop*) which takes value 1 if the firm cooperates exclusively with international partners, and local and international cooperation (*Local&InternationalCoop*) taking value 1 for firms cooperating both with local and international partners.

Additionally, the model includes a knowledge spillovers variable (*Spillovers*) which measures the external knowledge that firms perceive without recurring to cooperation. In PITEC, firms value on a Likert-scale (1 to 4) the relevance of various external sources of information (suppliers, clients, competitors, universities, technological centers and research institutes) during the last three years (*Knowledge sources*). The *Knowledge sources* variable is a direct measure of the importance of different sources of knowledge that are relevant to firms' innovation process. Following Belderbos et al. (2004), I extract the spillovers due to collaboration by taking as the spillover measure the residuals obtained from regressing the *Knowledge sources* variable in year *t* on the cooperation variable in year *t-1* and the set of sector dummies. Model (2) from which I extract the residuals which will represent the knowledge spillovers not due to cooperation has the following specification:

$$Knowledgesources_{i,t} = \alpha + \beta_1 Coop_{i,(t-1)} + \gamma Sector_i + \eta_{ii} \qquad (2)$$

The results of equation (2) are displayed in Appendix 4 for both services and manufacturing and the service subcategories of the taxonomy of Miozzi and Soete (2001).

3.3. Descriptive statistics

Table 1 shows the number and percentage of cooperating service and manufacturing firms. It also presents these figures for the three service categories of the Miozzi and Soete taxonomy. Additionally, it shows the percentage of firms that cooperate with each type of partner and the percentage of firms cooperating only with local partners, only with international partners and with both local and international partners.

As we can observe, about 9% of service firms cooperate at least with one external partner, while this percentage rises to 12% in the case of manufacturing firms. However, intragroup cooperation is more common in services. Comparing with other developed countries, external cooperation is not a widespread phenomenon in Spain. According to Eurostat (2008), 26% of innovative firms in the European Union-27 are involved in cooperative agreements with other firms and institutions. According to CIS3 (Communities, 2004), on average 17% of manufacturing firms were engaged in R&D cooperation in 1998-2000. Furthermore, we note that cooperation with firms from the same group is more common than cooperation with external partners, and, unlike it happened with external cooperation, intra-group cooperation is more common in the case of services.

[INSERT TABLE 1]

If we look at the type of partner, we note that most service and manufacturing firms mainly cooperate with suppliers and research institutions, which is consistent with the findings of other studies (Belderbos, Carree et al., 2004). In relation to partners' geographical location, there are differences between services and manufacturing: while manufacturing tend to cooperate with local partners, the majority of services collaborate with international partners.

Regarding the different services categories, science-based and specialized suppliers cooperate in a higher proportion (12.20%), while supplier-dominated services are the less cooperative (5.80%). Furthermore, for all categories, R&D institutions and suppliers are the most common types of partners. Although what is striking is that scale and information intensive services have similar innovative networks than those of manufacturing, while the other two categories have different networks. Scale and information intensive services tend to cooperate with local partners, as occurred with manufacturing, but supplier-dominated services and science-based and specialized suppliers services prefer to cooperate with international partners. In addition, scale and information intensive services collaborate with suppliers and research institutions in similar proportions, as occurs with manufacturing, while supplier-dominated services and science-based and specialized supplier services tend to cooperate more with institutions than with suppliers. Moreover, scale and information intensive services and manufacturing prefer to cooperate with clients over competitors, while the other two categories of services prefer competitors over clients.

Table 2 shows the mean and standard deviation of the variables used in the model differentiating between cooperating and non-cooperating services, manufacturing and the different categories of services.

[INSERT TABLE 2]

As we can see, all cooperating services and manufacturing give more importance to the external sources of knowledge, invest more in R&D, are larger and tend to be foreigners and exporters. Moreover, cooperating firms have a higher innovative productivity than firms that do not engage in R&D cooperation. All these differences are significant in the five samples.

There is only one significant difference between services and manufacturing, whether they cooperate or not: both cooperating and non-cooperating services expend more on R&D in comparison to manufacturing. This highlights the importance of services in the innovative activity of the entire national innovation system. Additionally, although not significant, manufacturing firms are larger in size than services.

Regarding differences between the services' categories, we can observe that science-based and specialized suppliers have the highest R&D intensity, while scale and information intensive services have the lowest R&D intensity. The opposite occurs with firm size: scale and information intensive services are the largest and science-based and specialized suppliers are smaller.

4. Results

[INSERT TABLE 3]

4.1. R&D cooperation and innovative productivity

Table 3 shows the results of model (1) applied to the service and manufacturing samples. Before analyzing the results on the influence of R&D cooperation in order to validate our hypothesis, it is appropriate to comment the effect of the other independent variables on firms' innovative productivity, since they indicate interesting similarities and differences between services and manufacturing. The first similarity is found in the positive influence of knowledge spillovers not due to cooperation, indicating that services and manufacturing that perceive and use information from external sources have a higher innovative productivity than firms not interested in external knowledge. The variable on knowledge spillovers, obtained from the residuals of the equation (2)[16], is positive and significant, indicating that both services and manufacturing that are able to perceive and use external information have a higher innovative productivity than the ones not interested in this type of knowledge.

However, in the case of firm size, results indicate a discrepancy: larger manufacturing firms have a higher innovative productivity than the smaller ones, but for services, firm size exerts a negative influence on innovative productivity. Although a larger size allows firms to carry out the necessary R&D to innovate and to exploit the potential market of each innovation (Love & Roper, 1999), this result indicates that this is not the case for services. This outcome is not entirely surprising since services' innovation is not based on economies of scale (Howells, 2002). Furthermore, innovation in services has an organizational character and this type of innovation has a negative association with firm size (Burns & Stalker, 1961), hence the most innovative and dynamic services are the smallest ones.

The cost and demand orientation of the innovative efforts significantly affects innovative productivity in the expected direction both for services and manufacturing. A demand orientation is more likely to translate into new product sales, but a cost orientation has a negative impact. Foreign firms located in Spain do not have a higher or lower innovative productivity than national firms, a result which is extensible for services and manufacturing. Global services (exporters) have a higher innovative productivity than those services that only operate at the national level, which confirms the positive relationship between services internationalization and the increase of their innovative production. In the case of manufacturing the *Global* variable is only significant at the 10%, therefore this result must be taken with caution.

Finally, lagged innovative productivity is significant and positive, indicating that firms that were successful innovators in the past are more likely to remain so in the future, since they are able to accumulate resources that can be reinvested in new innovative activities. This result is confirmed for both service and manufacturing firms. In this sense, Cefis and Ciccarelli (2005) also found that persistent innovators have benefits that are and remain higher than those of firms that are not persistent innovators.

4.2. R&D cooperation and R&D intensity

Our first hypothesis considered that the effect of R&D cooperation on services' innovative productivity is greater than the effect of R&D intensity, while for manufacturing the opposite occurs. Results in table 3 confirm our hypothesis. Although, as expected, R&D intensity has a significant influence on both service and manufacturing innovative productivity, the effect is greater for manufacturing firms. For manufacturing, the effect of R&D intensity is higher than the effect of any of the cooperation strategies, while for services the opposite occurs. Services' innovative activity characteristics make cooperation more efficient than investment in R&D, while for manufacturing R&D intensity is the most determinant variable of innovative productivity

4.3. Local and international R&D cooperation.

Regarding the influence of innovative cooperation variables, firstly it should be noted that intragroup cooperation is only significant in the case of services; however, its effect on innovative productivity is lower than any of the external cooperation options, whether local, international or both. This result suggests that the production of innovations new to the market requires the pooling of different complementary skills and resources, which can only be obtained outside the boundaries of the firm. Although we have to take into account that services, unlike manufacturing, are able to take advantage of their intra-organizational networks to bring to the market entirely new services.

Our second hypothesis considered that services benefit more from international cooperation, while local cooperation produce a greater impact on manufacturing innovative productivity, given the importance of geographical and cultural proximity in the innovative activity of each sector. This hypothesis is confirmed. As we can see, services that cooperate exclusively with local or international partners respond with higher innovative productivity than service firms that do not cooperate, but the value of the coefficient associated with exclusive local cooperation is lower than the one for exclusive international cooperation, both in size and significance. In the case of services, the resources offered by their foreign partners stimulate more their innovative activity; hence international allies seem to offer unique opportunities that local partners are unable to provide. Service firms find international relations more profitable as a result of greater internationalization, the adaptive nature of their innovative activity, the intangible component of their innovative knowledge and the higher rate of use of ICTs. Manufacturing firms also benefit from innovative cooperation, as long as they do not cooperate simultaneously with both local and international partners. Manufacturing firms that cooperate exclusively with local partners are the ones with the highest innovative productivity; hence the importance of geographical and cultural proximity on manufacturing innovative activity is confirmed.

In the case of firms cooperating with both local and international partners, hypothesis 3 considered that they should have a greater innovative productivity than firms cooperating with only one type of partner, and we considered this result extensible for both manufacturing and services. However, results indicate that this is only true for the case of services, for which international relations extend the benefits of R&D cooperation with local partners. In contrast, in the case of manufacturing, the results show that for them it is better to cooperate only with one type of partner rather than with both, as firms cooperating with both types of partners do not have a higher innovative productivity than non-cooperating manufacturing firms. Although firms cooperating with both types of partners face greater innovative opportunities, since they have access to more information and resources, they also incur in higher coordination and management costs as a consequence of administrating more complex innovation networks, which eventually may reduce their innovative output. In contrast, for services the benefits of integrating both local and international partners in their innovative networks compensate the costs of administrating these structures. As we have seen, services are much more R&D intensive, therefore they have higher *absorptive capacity*[17] (Cohen & Levinthal 1990), which allows them to obtain greater returns from R&D cooperation and to integrate successfully local and international partners in their innovative projects. In order to take advantage of partners' expertise, firms require a certain level of internal innovative effort (Cohen & Levinthal, 1990). According to Dosi et al. (1988), firms require internal innovative capacity to recognize, evaluate, negotiate and adapt the potentially available technology in the property of others.

4.4. Assessing differences between services categories

[INSERT TABLE 4]

Results in Table 4 show that the effect of technological cooperation, depending on the geographical location of the partners, is different for each service category. However, our fourth hypothesis is not confirmed, which considered that innovative cooperation should produce its greatest effects on science-based and specialized supplier services. Results indicate that the major differences between firms that cooperate and those that do not, are found in supplier-dominated services. Supplier- dominated services are small businesses with limited innovative capabilities, in which most innovations come from their suppliers of equipment, information and materials (Miozzo & Soete, 2001). Knowing the preferences of their customers is the key on the innovative success of these firms. (Djellal & Gallouj, 2005; Nasution & Mavoddo, 2008). The importance of the integration of vertical partners (suppliers and clients) in the innovative activities of these firms is crucial; hence we observe that supplier- dominated services that cooperate have a higher innovative productivity. The results indicate that the three options of cooperation are profitable to these firms, although exclusive cooperation with international partners is clearly shown as the most significant. Supplier-dominated services develop innovative tasks more standardized than those of the other categories of services; and, when innovative tasks are standardized, face to face contact is not as necessary as the one sometimes required in R&D cooperation (Dyer & Singh, 1998, Zaheer, McEvily et al., 1998).

Science-based and specialized supplier services also make profitable their innovative cooperation agreements and for them it is important to have both local and international partners. The higher absorptive capacity of these services allows them to engage in innovative networks composed of both local and international partners. In fact, only science-based and specialized supplier services cooperating with both types of partners respond with a higher innovative productivity. Exclusive local cooperation is not significant and there are indications of a significant positive effect of exclusive international cooperation. Other studies have also found that these services need to collaborate with the outside to innovate (Hollenstein, 2003; Tether, 2002). The increased complexity of innovations in this subgroup makes firms require of both local and international contacts. Moreover, these kinds of services are the only ones able to combine both types of partners effectively.

There are significance indications that scale and information intensive services benefit from exclusive local cooperation, while the other options of cooperation are not significant. However, R&D intensity, which represents both the internal and external expenditures in R&D, is the most important determinant of their innovative productivity, as it happened with manufacturing. This occurs because technological innovations in this subsector come from manufacturing firms (Miozzo & Soete, 2001). In these firms, suppliers are the main source of innovation, but investment in R&D is also very important (Sirilli & Evangelista, 1998).

5. Conclusions

New innovative challenges require multidisciplinary approach and interaction with different types of partners, which may be located in different parts of the world. The effectiveness of these partnerships depends on the characteristics of firms' innovative activity. In this sense, this study highlights significant differences between the effectiveness of innovative cooperation of services and manufacturing.

While industrial innovation is mainly affected by investment in R&D and the size of the firm, in services, technological cooperation is the most influential factor in their innovative productivity. Results show that services make their international agreements more profitable, unlike manufacturing that obtain more profit out of their linkages with local partners. Geographic and cultural proximity between cooperative partners turns out to be a key factor in industrial cooperative R&D relationships, given the importance of economies of scale and the tangible nature of its innovations. In the case of services, geographical and cultural proximity is not a determining factor of the effectiveness of R&D cooperation. For services, international innovative cooperation turns out to be more effective due to the intangible nature of their innovations and their high rate of use of ICTs. Results also indicate that local relations of service firms extend the benefits of R&D cooperation with international partners. However, for manufacturing is preferable to cooperate only with one type of partner, since the costs of coordinating and administrating networks composed of both local and international partners are greater than the benefits derived from having access to more knowledge and resources. Service firms are much more intensive in R&D, and therefore, are endowed with a greater capacity to absorb information, that allows them to take better advantage of their innovative cooperative relationships. This superior absorptive capacity makes the benefits of having access to greater knowledge (as a result of cooperating with both local and international partners) exceed the coordination and administration costs resulting from the cooperation with both partners.

But the differences are not unique between services and manufacturing. It is also evident that the effectiveness of innovative cooperation is different among different categories of service firms, according to Miozzi and Soete (2001) classification, based on the technological regime. Innovative collaboration is important for supplier-dominated, science-based and specialized supplier services, while the innovative success of scale and information intensive services is based on R&D intensity. Supplier-dominated services are the ones that get higher yields from cooperation, but only if they cooperate with international partners, showing that geographical and cultural proximity is not a determinant factor on the effectiveness of their innovative partnerships. Science-based and specialized supplier services require innovative networks both international and local for their R&D cooperation to be effective.

The results of this study advocate for policies that encourage partnerships in R&D. Continuing this line of thought, international partnerships of service firms must be encouraged, as well as local partnerships of manufacturing. Additionally, it should be take in consideration that only the most technologically complex services and those based on science, are capable to successfully integrate both local and international partners.

Footnotes

[1] In general, external R&D expenditures are more common in manufacturing.

[2] Logarithm of the sales of innovative products/services which are new to the market divided by the number of employees + 1

[3] Firms' R&D expenditures divided by total sales.

[4] Note that a partner located in Spain does not necessarily have to be a national firm, meaning, with Spanish capital.

[5] http://icono.publicaciones.fecyt.es/contenido.asp?dir=05%29Publi/AA%29panel

[6] The data panel includes a smaller sample of firms for the year 2003, and cannot be analyzed together with other questionnaires by significant changes in the questions. In the cooperation aspect, is only from 2004 when it just begins to obtain information

regarding the geographical location of the surveyed firms' partners, information that was not included in the 2003 questionnaire.

[7] NACE-93 is a code in the National Classification of Economic Activities that allows identifying and classifying different firms according to the economic activity. Each NACE-93 is a 5 digit code, each of which represents a more specific level of activity.

[8]Lööf (2007) also dispenses with these firms.

[9]Vega-Jurado et al. (2009) also choose to eliminate these firms.

[10]Most studies on technological cooperation only use data from innovative firms. Vega-Jurado et al. (2009), using PITEC data, find that the inclusion or exclusion of non-innovative firms in the sample does not affect the estimation of the parameters and reject the hypothesis that there is a sample selection bias. Same results are found by Love and Roper (1999) for the case of British firms.

[11]I do not include 2003 data because R&D partners' location is not specified, and 2009 are also not included because the data were not available at the time this study was conducted.

[12]Section 3.3 defines each of the variables used in model (1)

[13]PITEC distinguishes between innovations new to the market, i.e. which have not been introduced before by competitors and innovation new to the firm, i.e. products that were already available in the market.

[14] By using R&D intensity, rather than it absolute value, I control for scale effects.

[15]Appendix 1 presents the different industries and services included in the model, classified according to the NACE-93 classification.

[16]Appendix 2 shows the regression results.

[17]R&D intensity is associated with the absorptive capacity of the firm (Cohen & Levinthal, 1990). These are the firms that have developed their internal innovative activity the most, making more profitable the benefits of their innovative cooperation agreements.

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Table 1.Number and percentage of R&D cooperating firms

	SERVICIES	MANUFACTURING FIRMS	SUPPLIER-DOMINATED	SCALE & INFORMATION INTENSIVE	SCIENCE-BASED & SPECIALIZED SUPPLIERS
Coop	9,27%	12,02%	5,80%	8,74%	12,20%
Intragroup	21,59%	19,14%	17,81%	20,62%	24,84%
Suppliers	5,35%	7,74%	2,91%	5,41%	7,02%
Clients	1,05%	1,86%	0,66%	1,00%	1,34%
Competitors	1,12%	1,58%	0,79%	0,86%	1,50%
Institutions	6,82%	7,94%	4,64%	5,38%	9,24%
LocalCoop	2,73%	4,42%	1,82%	4,67%	2,15%
InternationalCoop	3,96%	3,74%	2,25%	1,83%	6,48%
Local&InternationalCoop	2,57%	3,86%	1,72%	2,24%	3,38%
Number of observations	10006	17924	3014	2677	4315

Source: author's elaboration with PITEC data.
Note: "Coop" refers to cooperation with external partners, therefore it excludes intragroup cooperation.
Institutions include universities, technological centers and research institutes.

Table 2. Mean and standard deviation for cooperating and non-cooperating firms

	SERVICIES		MANUFACTURING FIRMS		SUPPLIER-DOMINATED		SCALE & INFORMATION INTENSIVE		SCIENCE-BASED & SPECIALIZED SUPPLIERS	
	COOP YES	**COOP NO**	**COOP YES**	**COOP NO**	**COOP YES**	**COOP NO**	**COOP YES**	**COOP NO**	**COOP YES**	**COOP NO**
Knowledge sources	9,274	5,816	8,968	6,220	8,628	5,301	8,397	5,555	9,886	6,368
	(3,862)	(3,932)	(3,684)	(3,864)	(3,913)	(3,950)	(3,865)	(3,615)	(3,736)	(4,043)
R&D intensity	0,287	0,114	0,054	0,042	0,121	0,064	0,050	0,030	0,449	0,206
	(0,399)	(0,243)	(0,101)	(0,102)	(0,234)	(0,177)	(0,144)	(0,114)	(0,444)	(0,308)
Size	1,900	1,719	2,159	1,740	2,124	1,910	2,348	2,055	1,622	1,358
	(0,830)	(0,806)	(0,616)	(0,544)	(0,898)	(0,839)	(0,841)	(0,815)	(0,677)	(0,607)
Demand	2,135	1,668	2,276	1,883	1,862	1,412	2,094	1,654	2,238	1,870
	(0,844)	(0,978)	(0,697)	(0,909)	(0,927)	(0,984)	(0,865)	(0,984)	(0,788)	(0,922)
Costs	1,424	1,240	1,727	1,433	1,359	1,233	1,582	1,342	1,377	1,178
	(0,799)	(0,840)	(0,789)	(0,871)	(0,783)	(0,831)	(0,788)	(0,840)	(0,803)	(0,841)
Foreign	0,151	0,064	0,288	0,095	0,131	0,045	0,299	0,108	0,090	0,051
	(0,358)	(0,245)	(0,453)	(0,294)	(0,338)	(0,207)	(0,458)	(0,311)	(0,287)	(0,219)
Global	0,670	0,397	0,932	0,807	0,525	0,247	0,658	0,524	0,724	0,427
	(0.470)	(0,489)	(0,250)	(0,394)	(0.500)	(0,431)	(0,475)	(0,499)	(0.447)	(0,494)
Innovative productivity	2,821	1,441	2,484	1,680	2,422	0,995	2,686	1,289	3,017	1,873
	(2,182)	(2,036)	(2,217)	(2,155)	(2,248)	(1,794)	(2,310)	(2,039)	(2,079)	(2,118)

Source: author's elaboration with PITEC data.
Note: "Coopera" refers to cooperation with external partners, therefore it excludes intragroup cooperation

Table 3.
Regression results for innovative productivity, services and manufacturing firms

	SERVICIES	MANUFACTURING
LocalCoop	0,530**	0,492***
	(0,250)	(0,158)
InternacionalCoop	0,775***	0,325***
	(0,206)	(0,164)
Local&InternationalCoop	0,921***	0,203
	(0,267)	(0,178)
Intragroup	0,327***	0,104
	(0,111)	(0,090)
Spillovers	0,153***	0,108***
	(0,012)	(0,009)
R&D intensity	0,388**	0,833***
	(0,179)	(0,292)
Size	-0,156***	0,302***
	(0,072)	(0,078)
Demand	0,575***	0,583***
	(0,059)	(0,047)
Costs	-0,267***	-0,144***
	(0,058)	(0,044)
Foreign	-0,076	0,086
	(0,185)	(0,121)
Global	0,546***	0,185*
	(0,098)	(0,099)
Innovative productive	0,931***	0,833***
	(0,035)	(0,028)
Sector	Included	Included
Constant	-6,004***	-3,138***
	(1,772)	(0,197)
Number of observations	10006	17924
Number of groups	3678	5706
Wald chi2	1967,60***	1912,03***
Log Likelihood	-12403,225	-24442,136
Sigma_u	1,529*** (0,109)	1,841*** (0,084)
Sigma_e	2,982*** (0,053)	2,959*** (0,039)
Censored observations	6280	10575
Non-censored observations	3726	7344

Source: author's elaboration. Random effects Tobit model.
**significant at 10%, ** 5%, ***1%. Standard deviations in brackets.*

Table 4
Regression results for innovative productivity, services categories

	SUPPLIER-DOMINATED	SCALE & INFORMATION INTENSIVE	SCIENCE-BASED & SPECIALIZED SUPPLIERS
LocalCoop	1,038*	0,812*	-0,093
	(0,626)	(0,421)	(0,361)
InternacionalCoop	1,512***	0,910	0,415*
	(0,534)	(0,628)	(0,227)
Local&InternationalCoop	1,186*	0,253	0,781***
	(0,677)	(0,609)	(0,323)
Intragroup	-0,026	0,289	0,441***
	(0,250)	(0,246)	(0,142)
Spillovers	0,217***	0,190***	0,104***
	(0,025)	(0,027)	(0,014)
R&D intensity	0,351	2,393***	0,183
	(0,553)	(0,669)	(0,190)
Size	-0,232*	0,024	0,035***
	(0,140)	(0,148)	(0,116)
Demand	0,589***	0,482***	0,584***
	(0,129)	(0,127)	(0,077)
Costs	-0,298**	-0,409***	-0,133*
	(0,131)	(0,130)	(0,073)
Foreign	0,077	0,029	-0,549**
	(0,461)	(0,312)	(0,277)
Global	0,575***	0,356	0,522***
	(0,226)	(0,219)	(0,126)
Innovative productive	1,231***	1,108***	0,712***
	(0,071)	(0,075)	(0,046)
Sector	Included	Included	Included
Constant	-4,516***	-7,169***	-2,520***
	(0,416)	(2,055)	(0,251)
Number of observations	3014	2677	4315
Number of groups	1236	1009	1577
Wald chi2	599,76***	528,44***	635,47***
Log Likelihood	-2877,698	-2981,212	-6464,364
Sigma_u	1,341*** (0,247)	1,603***(0,239)	1,576*** (0,136)
Sigma_e	3,495*** (0,125)	3,223*** (0,119)	2,633*** (0,065)
Censored observations	2223	1815	2242
Non-censored observations	791	862	2073

Source: author's elaboration. Random effects Tobit model.
**significant at 10%, ** 5%, ***1%. Standard deviations in brackets*

Appendix 1. Distribution of firms across activities

Activity NACE-93	Number of observations
SERVICIES	**10.006**
SUPPLIER-DOMINATED	***3.014***
Education	121
Other health and social activities	823
Hospitality	102
Construction	823
Sale and repair of motor vehicles	135
Other business	897
Real state activities	113
SCALE AND INFORMATION INTENSIVE	***2.677***
Wholesale business	1.219
Retail trade	244
Transport	169
Activities for transportation, travel agencies	165
Postal and courier activities	14
Telecommunication Services	141
Financial intermediation	600
Motion picture and video	78
Radio and television activities	47
SCIENCE-BASED AND SPECIALIZED SUPPLIERS	***4.315***
Renting of machinery and equipment	77
Software	1.867
Other computer activities	426
Research and development	423
Architectural and engineering	1.164
Technical testing and analysis	358
MANUFACTURING FIRMS	**17.924**
Food and drinks	2.151
Tobacco	7
Textile	712
Clothing and leather	194
Leather and footwear	192
Wood and cork	298
Paper	308
Publishing, printing and reproduction	330
Chemistry (excluding pharmaceuticals)	1.980
Pharmaceuticals	545
Rubber and plastics	1.131
Tile and ceramic tile	160
Non-metallic mineral products	815
Ferrous metal products	307
Non-ferrous metal products	203
Metal products (except machinery)	1.754
Machinery and equipment	2.537
Office machinery and computers	69
Machinery and electrical equipment	923
Electronic components	195
Radio, TV and communication	339
Medical and precision instruments, optical	803
Motor vehicles	740
Shipbuilding	111
Aircraft and spacecraft	74
Other transport equipment	108
Furniture	603
Games and Toys	44
Other articles	187
Recycling	104

Source: author's elaboration. PITEC data.

Appendix 2. Description of the variables

Variable	Description
Local cooperation	1 if the business unit reported engagement in innovation in cooperation strategy exclusively with local partners, else zero.
International cooperation	1 if the business unit reported engagement in innovation in cooperation strategy exclusively with international partners, else zero.
Local and International cooperation	1 if the business unit reported engagement in innovation in cooperation strategy with both local and international partners, else zero.
Intragroup cooperation	1 if the business unit reported engagement in innovation in cooperation strategy its group, else zero.
Sources of knowledge	Importance of the sources of knowledge for the firm□s innovation process (1-4).
Spillovers	Importance of the sources of knowledge for the firm□s innovation process. Constructed as residual from the auxiliary regression of sources of knowledge taken from t survey on a cooperation dummy taken from t-1 survey.
R&D intensity	Total innovation expenditures/total sales
Size	Logarithm of number of employees
Demand	Importance of demand-enhancing objectives for the firm□s innovations. Constructed as sum of scores (1-4) on 4 categories of objectives, relating to products quality and new products and markets.
Costs	Importance of cost-saving objectives for the firm□s innovations Constructed as a sum of scores (1-4) on 4 categories of objectives, relating to processes, labour,
Foreign	1 if more than 50% of firm□s capital is owned by foreigners and its headquarters is not located in Spain, else zero
Global	1 the firm sells its products or services in Spain and outside Spain, else zero
Innovative productivity	Logarithm (1+(sales of products-services new to the market/number of employees)

Note1: all independent variables are measured in t-1, except for the spillover variable.
Note2: innovative productivity is also included as an independent variable measured t-1

Appendix 3. Correlations

SERVICES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
LocalCoop (1)	1											
InternacionalCoop (2)	-0,035	1										
Local&InternationalCoop (3)	-0,027	-0,032	1									
Intragroup (4)	-0,152	0,213	0,241	1								
Services spillovers (5)	-0,043	-0,033	0,044	0,165	1							
Size (6)	0,085	-0,056	0,062	0,052	-0,013	1						
R&D intensity (7)	-0,014	0,185	0,109	0,156	0,125	-0,356	1					
Demand (8)	0,059	0,066	0,087	0,168	0,252	-0,111	0,147	1				
Costs (9)	0,023	0,005	0,064	0,110	0,180	0,124	-0,003	0,389	1			
Foreign (10)	0,170	-0,028	0,050	-0,012	-0,044	0,183	-0,057	-0,013	-0,016	1		
Global (11)	0,050	0,091	0,111	0,052	0,094	0,058	0,004	0,117	0,024	0,135	1	
Innovative productivity (12)	0,051	0,109	0,120	0,166	0,141	-0,102	0,152	0,403	0,097	0,006	0,153	1

MANUFACTURING FIRMS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
LocalCoop (1)	1											
InternacionalCoop (2)	-0,043	1										
Local&InternationalCoop (3)	-0,043	-0,040	1									
Intragroup (4)	0,164	0,233	0,308	1								
Manufacturing spillovers (5)	-0,053	0,001	0,057	0,166	1							
Size (6)	0,158	0,031	0,193	0,142	0,104	1						
R&D intensity (7)	-0,008	0,033	-0,001	0,053	0,062	-0,251	1					
Demand (8)	0,055	0,063	0,103	0,142	0,272	0,034	0,080	1				
Costs (9)	0,047	0,046	0,088	0,115	0,220	0,136	0,019	0,424	1			
Foreign (10)	0,198	-0,026	0,138	0,042	-0,049	0,341	-0,073	-0,007	0,032	1		
Global (11)	0,043	0,052	0,074	0,047	0,099	0,239	-0,092	0,104	0,038	0,132	1	
Innovative productivity (12)	0,053	0,062	0,075	0,139	0,141	0,048	0,060	0,321	0,111	0,027	0,070	1

Source: Author's elaboration. PITEC data

Appendix 4. Regression results for knowledge spillovers calculus (residuals)

	SERVICIES	MANUFACTURING	SUPPLIER-DOMINATED	SCALE & INFORMATION INTENSIVE	SCIENCE-BASED & SPECIALIZED SUPPLIERS
Coopera	2,854*** (0,128)	2,217*** (0,088)	2,504*** (0,303)	1,965*** (0,253)	2,760*** (0,174)
Constant	3,214*** (1,069)	6,376*** (0,077)	4,743*** (0,374)	3,214*** (0,977)	7,821*** (0,135)
Sector	Included	Included	Included	Included	Included
Number of observations	10376	17933	3014	2677	4315
F( )	69,31***	68,80***	15,07***	17,64***	117,63***

Source: Author's elaboration. OLS model. Dependent variable: Knowledge sources
**significant at 10%, ** 5%, ***1%. Standard deviations in brackets.*