COMPLEMENTARITIES BETWEEN UNIVERSITIES AND TECHNOLOGY INSTITUTES: New empirical lessons and perspectivas

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This paper investigates the different role played by universities and technology institutes in supporting the innovation activities of firms. Comparing the characteristics of the Spanish firms collaborating with these agents allows us to better define complementarities among the target groups of these organizations. Our findings show that those firms collaborating with universities are bigger, have higher internal capabilities and are less dependent on their external relationships while firms collaborating with technology institutes are smaller, have weaker internal capabilities but are more open to their environment, and thus more reliant on external sources. We point to the implications of these findings for regional development. Universities have a role in supporting the more technologically advanced firms. Technology institutes on the other hand, are able to help those firms, which though also quite advanced, require more external help in their innovation processes. These results should help policy makers in the definition of more complex regional strategies, and the provision of tools aimed at different goals. Managers of universities, technology institutes and client firms should find these results of help in developing more positive interactions with one another.

Keywords: Universities, Technology Institutes, Systems of innovation, Cooperation, Innovation policy

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1. Introduction

Firms' utilization of external sources of knowledge has grown impressively in the last two decades (Hagedoorn 2002; Amara and Landry 2005), which has increased the interest of academics and policy-makers in this area. On the side of government and policy-makers, several initiatives have been implemented to foster collaboration between firms and external sources of knowledge (Geroski 1992; Martin 1996). In the academic arena, several studies have tried to analyse the factors leading firms to utilize the knowledge embedded in other organizations such as suppliers, clients, competitors and research organizations (Fritsch and Lukas 2001; Tether 2002; Cassiman and Veugelers 2002; Miotti and Sachwald 2003; Belderbos, Carree, et al. 2004, among others). However, these empirical works have studied research organizations as a whole, and do not distinguish among the factors that drive firms to select a particular type of research organization such as a university, a Public Research Organization (PRO) or a Technology Institute (TI). For example, Miotti and Sachwald (2003) consider interactions with "public institutions" (collectively accounting for universities and PROs), while Cassiman and Veugelers (2002) label PROs, private research institutions and universities as "research institutions". Belderbos, Carree, et al. (2004) in their study also lump together research institutions and universities. However, there are several differences among these various types of organization, which, in our opinion, have not been acknowledged.

Some authors have argued that they both differ and show complementarities (Smith 1997; Beise and Stahl 1999; Fuellhart and Glasmeier 2003). The present study aims to shed more light on this type of research. More precisely, our main objective is to analyse the role of innovation partner to Spanish firms played by two types of research organization: TIs (which includes research and technology organizations and technology centres) and universities. The intention is to provide a better understanding of the potential complementarities between TIs and universities as support organizations of firms` innovation processes. In particular, we are able to distinguish at least two dimensions of complementarity between Spanish universities and TIs: i) types of clients; and ii) types of needs covered. This distinction could be useful to policy-makers designing comprehensive regional development strategies, by providing specific tools addressed to different agents and goals. This work focuses on the first dimension of complementarity.

We also have two secondary objectives. First, we want to delve into the role played by TIs in supporting innovative processes of firms. These types of organizations are found in the majority of developed countries and usually show a strong regional focus (Arnold, Rush, et al. 1998; Mas-Verdú 2007), but have been rather ignored by the economics literature. Some examples of TIs in countries other than Spain include the Japanese Kosetsushi Centres, the US Manufacturing Technology Centres or the Italian Real Service Centres. Second, our analysis should help to clarify the role played by universities in territorial development, as the innovation partners of firms. Of course, universities influence regional development via many channels (see for example, Cohen, Nelson and Walsh 2002; Molas-Gallart, Salter, et al. 2002; Goldstein and Drucker 2006), but it is their role as direct providers of knowledge intensive services to firms that has been emphasized in recent years. Although a vast body of economic research has analysed university-industry links (Jaffe 1989; Mansfield 1991; Stephan

1996; Narin, Hamilton and Olivastro 1997; Henderson, Jaffe and Trajtenberg 1998; Mowery, Nelson, et al. 2001; Agrawal and Henderson 2002; among others), these studies usually focus on a rather limited number of technological environments. Therefore, in order to understand differences among sectoral contexts, it is necessary to undertake large-scale cross-industry studies of university-industry links (Laursen and Salter 2004) which should provide the opportunity to examine what factors influence the propensity of firms to draw on university research (Klevorick, Levin, et al. 1995).

We tackle with the issue of complementarities between universities and TIs and our two secondary objectives, by analysing and comparing the characteristics of two groups of firms: those that collaborate with TIs and those that interact with universities. We look particularly at the general characteristics of these firms (such as size, export behaviour and sector of activity), their innovation processes and their innovation results. The empirical analysis is conducted in two steps. First, we carry out an in-depth descriptive analysis and, second, we take and econometric approach using a random effects probit model. The data are from the Innovation Panel of the Spanish Institute of Statistics (2003-2004).

The paper is organized as follows. In the next section, we review the literature on the role of universities and TIs as support organizations for firms` innovation processes. We then describe the data and the empirical strategy and go on to analyse our results. The final section provides a discussion of these results and our conclusions.

2. Previous studies and open debates

Universities as technology partners

The role of universities as drivers of regional development has been widely analysed in the academic literature (Goldstein and Drucker 2006). The "third mission" of the university has been the subject of many recent studies through an approach within the "triple-helix" concept, which considers that nowadays regional development is based on the interactions among three entities, universities, firms and public administrations, with each being a link in the same chain (Etzkowitz and Leyesdorff 1999, 2000). None of these spheres is prioritized; what is crucial is the convergence of communications, networks and organizations.

For these reasons, many OECD country governments have been supporting increased interaction between universities and industry (Cohen, Nelson and Walsh 2002). These initiatives are often premised on the expectation that university-industry interactions can increase innovation rates in the economy (Spencer 2001). Aggregate studies show that the influence of universities on the private innovative outcomes of neighbouring firms is quite important (Jaffe 1989), especially for small and medium sized enterprises (SMEs) (Acs, Audretsch and Feldman 1994; Feldman 1994). These results are frequently interpreted according to the importance of face to face contacts to transfer tacit knowledge. However, none of these studies provides clarification on the channels involved in these interactions (Breschi and Lissoni 2001). This is rather important when we consider that the variety of these channels of influence is very high (Molas-Gallart, Salter, et al. 2002). For example, not only direct

provision of knowledge intensive services to firm, but also training of graduates (Nelson 1986; Narin, Hamilton and Olivastro 1997), basic research (Feldman 1994; Feller, Ailes and Roessner 2002) and other activities have been highlighted as major ways that universities influence the productive sector.

There is another view that points to the formidable barriers to the exploitation of university support for SMEs with weak internal research and development (R&D) capacity, which constitute much of the productive sectors even in developed countries. These barriers exist because these firms usually do not know what are their real requirements, or have problems in expressing them (Lambrecht and Pirnay 2005), they do not know what types of services they need to develop innovations (Izushi 2003), or which knowledge providers have the most relevant capabilities (Geisler 1997; Teubal 1997); and they encounter difficulties when trying to communicate with them (Smallbone, North and Leigh 1993). The results of econometric studies corroborate this view. They agree that the firms that interact more with universities are larger firms which devote more internal efforts to R&D and belong to the high technology sectors (Fritsch and Lukas 2001; Cassiman and Veugelers 2002; Miotti and Sachwald 2003; Belderbos, Carree, et al. 2004).

These problems imply that SMEs need support to be easily accessible and customized (Sánchez 1999; Fuellhart and Glasmeier 2003), thus requiring a very active role on the part of the providers of knowledge who need to help firms identify and articulate their needs. These knowledge providers, therefore, should be proactive and develop knowledge not only about their clients, but also about the markets in which they work. Knowledge support organizations have to speak the same language as firms (Smallbone, North and Leigh 1993). That is to say, they have to develop “technoeconomic” capabilities (Galli and Teubal 1997). However, it is almost impossible in the universities (or PROs) to find researchers with the specific “technoeconomic” capabilities needed to support SMEs’ innovation processes (Rolfo and Calabrese 2003). As a consequence, for traditional SMEs the idea of using science inputs is foreign (Arnold and Thuriaux 1997).

Another factor that explains the shortcomings in university-industry linkages is that universities do not have sufficient incentive to support SMEs, and especially SMEs that are not technology or science based. Universities prefer to work with large firms because of their bigger financial resources and greater technological capabilities, which give reputation and the possibilities of future job offers (Shapira, Roessner and Barke 1995; Beise and Stahl 1999). In addition, although there is an increasing trend towards more applied research in universities, staff profiles are mainly purely scientific or technological (Rolfo and Calabrese 2003) and university researchers usually prefer to perform research rather become involved in development (del Barrio-Castro and Garcia-Quevedo 2005). In relation to the smaller universities, MacPherson and Ziolkowski (2005) have argued that they can deliver useful inputs to local industrial firms via relatively simple technical assistance. The debate over the role of universities is open and more evidence is needed on all these aspects.

Specificities in the role of TIs

As has been noted, TIs exist in most developed countries and are important components of the regional and national knowledge infrastructure (Arnold, Rush, et al. 1998; Mas-Verdú 2007). They provide firms with a broader portfolio of services that differ from those offered by universities and private firms (Leitner 2005). These research institutions focus not only on applied research and technology development, but also on the provision of support services, such as consultancy, technical assistance, diagnosis and so on, thus serving firms that otherwise would have no such support (Izushi 2005). They can be public or privately owned and, although they usually receive public funding, private sources of funding are increasing (Leitner 2005). Some examples of such organizations that in our view have been overlooked in the research literature are the Japanese Kosetsushi Centres, the USA Manufacturing Technology Centres, the Italian Real Service Centres and the Spanish TIs.[1]

The Japanese Kosetsushi Centres are local technology centres that perform the dual function of provision of tiered modernization services and applied, near-market research. These centres maintain regular interaction with client firms to provide modernization services aimed at solving the immediate needs of firms and to steer them on to longer term paths involving more risk, toward innovation capacity building (Izushi 2003, 2005).

The USA Manufacturing Technology Centres provide information and education for local SMEs, demonstrate advanced technology, help firms evaluate their needs and implement new technologies, and support workforce training (Shapira, Roessner and Barke 1995). These centres exist as separate non-profit corporations or as a part of another organization, e.g. a university, a stage agency or an economic development group. They form a network of technology assistance and service providers known as the Manufacturing Extension Partnership (Shapira 2001).

The Italian Real Service Centres focus on collective rather than individual needs and provide firms with a range of technical services including industrial research, dissemination of information on markets, fashion trends, standards and regulations, upgrade and transfer of technology, training and testing, certification services, etc. There has been a deliberate attempt in Italy to involve private enterprise in the actual day-to-day functioning of these Real Service Centres through membership which involves a membership fee. These Real Service Centres are characterized by a well integrated public/private mix at regional level and have attracted much international attention (Brusco 1992; Pyke 1994).

The Spanish TIs are private, non-profit organizations that perform a wide range of knowledge-based activities oriented to enhancing firms' competitiveness. Most were created through joint efforts by private and public agents (mainly regional), which are represented on their boards of directors. Some also have involvement of agents from the scientific community. They are key organizations in the

[1] There are other types of organizations in other countries, that are on the whole much bigger and more research-oriented, that originated in the public sector including the Fraunhofer Institutes, the Dutch TNO and Finland's VTT. The Spanish TIs are fairly heterogeneous and a few include some of the features (although on a smaller scale) of these larger organizations.

Spanish National Innovation System (NIS) because of their size and closeness to the productive sector (Modrego-Rico, Barge-Gil and Núñez-Sanchez 2005). There are 82 TIs across Spain but their regional distribution is rather unequal. Some regions, such as País Vasco and Comunidad Valenciana, have more than 15 TIs, which are well established (more than ten years). Others, such as Castilla y León, have made efforts to increase the numbers and sizes of TIs in their territories in recent years. However, the technology policy of some regions has not been directed to supporting the establishment of TIs. There are regions with only one or two TIs, although interest in increasing their numbers is growing. Spanish TIs receive some 40% of their revenue from public bodies, the remaining 60% coming from contracts with the private sector of which around 65% are related to R&D projects. These figures mean that the orientation of the Spanish TIs to R&D is higher than in the Japanese Kosetsushi Centres, the USA Manufacturing Technology Centres and the Italian Real Service Centres

All these types of organizations however, show some important differences when compared to universities. First, their main purpose is to increase the competitiveness of their customer firms; universities usually have a wider variety of objectives. Second, they provide firms with a wide range of knowledge intensive services, while universities mainly offer training, access to equipment and assistance on R&D projects. Third, TIs' staff has a wider focus. Rather than being completely centred on scientific aspects, TIs' staff encompass knowledge about technology and generally also capabilities in management. Thus, they are able to offer "technoeconomic capabilities". Fourth, TIs are usually more immersed in the regional economy and their councils include relevant local stakeholders from both the public and private sectors. Universities are becoming more embedded in their local contexts, but there are still knowledge gaps which make interaction with local agents rather difficult. Fifth, TIs show flexible management procedures, in contrast to the bureaucracy of universities.

TIs are supposed important for supporting the modernization and innovation activities of SMEs. However, there has been little research undertaken on this aspect and there are few studies that investigate the complementarities or redundancies among TIs and universities, an exception being Izushi (2005), which evaluates and compares the users of both Kosetsushi Centre and universities. His results show that users rank the services of the Kosetsushi Centres significantly higher in terms of their: (i) ability to perform the services promised; (ii) ability to communicate; (iii) ability to provide prompt services, but rates them as equal to universities in terms of the level of technical knowledge received by users.

Previous discussions about the role of universities and TIs as support organizations of firms` innovative efforts highlights the need for detailed empirical studies aimed at shedding light on the complementarities existing between the. In what follows, we will try to accomplish this task.

3. Empirical study

The data

The data on firms' characteristics comes from the Innovation Panel of the Spanish Institute of Statistics for 2003 and 2004 . This database, which have only recently become available, are a very rich source of information on firms' innovation processes, although they are biased towards firms with internal innovation capabilities, which must be taken into account when interpreting the results. The sample includes 7,283 firms with R&D expenses and/or which employ more than 200 people. In addition, 1,437 were included in 2004. Of these new firms, 438 had external but not internal R&D expenditure and 999 firms with no recorded innovation expenses and fewer than 200 employees.

The data allow us to analyse the general characteristics of firms, such as size, export behaviour, ownership, sector of activity, and the region in Spain where the R&D department is located. But the main advantage is related to information on the innovation processes of firms which allows us to explore different features involved in their innovation efforts (innovation expenses and internal R&D activities), information sources, barriers to innovation and several innovation outputs. Moreover we can distinguish the type of technological partner with which the firm has collaborated. In our study, we distinguish between TIs and universities. Table 1 presents the number of firms collaborating with them.

(Insert Table 1 about here)

Empirical strategy

The empirical objective is to compare the characteristics of two groups of firms: those collaborating with TIs, but not with universities (TIs) and those collaborating with universities but not with TIs (Universities). In order to explore firms' characteristics, we adopt an empirical strategy involving two steps. First, we describe the characteristics, innovation processes and outputs of the firms. Second, we carry out an econometric analysis by means of a random effects probit model. As can be seen from Table 1, there is a group that collaborates with both of these types of organization. The analysis of this group is not relevant to study the first dimension of complementarity so that, for clarity and simplicity, we not include them in the general description.

For the descriptive analysis we start with a study of the general characteristics of the firms in our sample, and especially economic aspects (such as income, number of employees, volume of exports), ownership information (if the firm belongs to a group, existence of foreign capital), sector of activity and the regional distribution of the firms' R&D staff (as a proxy for the regional distribution of our sample). Next we explore the different issues related to firms' innovation processes including innovation expenses, characteristics of internal R&D activities (such as staff, type of R&D and funding), sources of information and the main barriers to innovation activities. Finally, we explore several technological and organizational outcomes in terms of product and process innovations, industrial and intellectual property and some organizational innovations.

Alongside this descriptive analysis, where the variables are continuous, we employ two measures of centrality: mean and median values in order to avoid data from a minority of firms having disproportionate influence on our results. The median value best represents the typical firm in each group. The p-values in the tables come from a two sample t-Test for equal means and for a Chi-square test, respectively. In the case of the median values the Chi-square test is performed taking into account the number of observations above and below the median in each group. Availability of data for two years (2003-2004) is an additional check of robustness because the firms in each group vary across years, while the characteristics of the typical firm remain fairly stable. In addition, the econometric analysis (our second empirical step) will further add to the robustness of the firm characteristics in terms of their probability of cooperating with a TI or a university.

Results: descriptive analysis

The descriptive results are presented in three sub-sections: i) general characteristics (size, export activities, area of activity); ii) innovation activities (strategies, innovation expenses, barriers to innovation); and iii) results of the innovation process.

General characteristics

Data from Tables 2 to 4 show that there exist sharp differences between the characteristics of firms collaborating with TIs and those collaborating with universities.

The mean and median values for income and number of employees show that firms collaborating with TIs are usually much smaller than those collaborating with universities (Table 2). However, there are changes across the two years. The mean and median sizes of firms increases for those collaborating with TIs but decreases slightly for those collaborating with universities. Also interesting is that firms collaborating more frequently with universities are more likely to be those that belong to a group and to a foreign multinational. Despite the differences in size and property, both the propensity to export and the export intensity (the percentage of income due to exports) are substantially higher among firms collaborating with TIs than among firms collaborating with universities.

The sectoral distribution of firms also varies (Table 3). We divided manufacturing into four sectors according to OECD (2005): low-tech, low-medium-tech, medium-high-tech and high-tech . Among the service sectors, we identified knowledge intensive services. We can see that firms in low-tech sectors collaborate with TIs and universities equally. Firms in low-medium tech sectors are more likely to collaborate with TIs than universities. But, the most pronounced differences occur in high tech sectors. Firms in these sectors collaborate with universities, but only very infrequently with TIs.

Overall, these results support the view that universities focus more on large firms with bigger resources and which are more high-tech, while TIs tend to support smaller (usually national) firms in more traditional sectors.

(Insert Table 2 about here)

(Insert Table 3 about here)

Another characteristic of interest is where the firms are located. We do not have data on actual location, but we have information on the regional distribution of firms' R&D staff, which we can use as a proxy for firm location. Table 4 shows that firms collaborating with TIs have a higher percentage of R&D employees in regions such as País Vasco, Comunidad Valenciana, Castilla y León, Navarra and La Rioja. The first four (together with Cataluña) are the regions with a highest number of TIs and La Rioja is geographically situated between País Vasco and Navarra, so our results fully support the importance of geographical proximity to TIs. Those firms collaborating with universities have a higher percentage of their R&D staff in Madrid, Cataluña, Andalucía, Aragón, Cantabria, Castilla La-Mancha and Galicia.

(Insert Table 4 about here)

Innovation activity

This section investigates the innovation processes of each group of firms in terms of innovation expenses, internal R&D activities, type of research and funding, strategies used to access external knowledge and the barriers to innovation activities. These aspects are very revealing of the characteristics of firms` innovation processes but some of them have rarely been exploited in the existing empirical studies.

Innovation expenses

Firms with higher innovation expenses (according to both mean and median) are those that collaborate with universities (Table 5). The same applies for innovation effort (innovation expenses/income), although wide disparities exist between mean and median values. Finally, the distribution of innovation expenses across different innovation activities (internal R&D, external R&D, non-R&D activities) shows that firms collaborating with TIs allocate a high proportion of their innovation expenses to external R&D activities while those collaborating with universities are more focused on inhouse R&D.

(Insert Table 5 about here)

Internal R&D activities

In line with previous results, we can see that the size of R&D staff is higher among those firms collaborating with universities than among those collaborating with TIs (Table 6). We can see that there are also differences in the type of R&D performed reflected by the composition of R&D staff and R&D expenses. Firms collaborating with universities have higher percentages of researchers on their R&D staff and are more oriented towards applied R&D whereas firms collaborating with TIs employ a higher percentage of research assistants and are more oriented to technological development activities. The way that R&D is financed also differs. Firms collaborating with TIs make less use of internal financing and depend to a greater extent on public funding.

From the above results, it can be concluded that firms collaborating with TIs show a smaller internal research capacity which is reflected in the fact that: (i) they are smaller; (ii) they are less innovation-intensive; (iii) their innovation activities are less oriented to internal R&D; (iv) their inhouse R&D is focused more on technological development (at the expense of applied research) and is performed by less well qualified staff; and (v) they have lower levels of internal financial resources to fund their R&D activities and are more depending on regional and national public funding.

(Insert Table 6 about here)

Sources of information

We have seen that firms that collaborate with TIs are much more oriented to external R&D. In this section we analyse the importance given by firms to different external sources of information. Firms were asked to rank them from 1 (very important) to 5 (not important) only in 2004.

The results in Table 7 show that firms collaborating with TIs are not only relatively more focused on external agents, they also, in absolute terms, generally assign more importance to them. These include suppliers, customers, competitors, consultants or R&D firms and TIs. Firms that collaborate with universities, on the other hand, assign more importance to universities and PROs.

(Insert Table 7 about here)

Barriers to innovation activities

Again, firms were asked to rank the importance of different barriers to innovation activities from 1 (very important) to 5 (not important) only in 2004.

The main barriers to innovation are related to cost (Table 8). Firms consider innovation activities to be very expensive. They generally lack both internal funds and more especially external finance. These barriers apply equally to both groups of firms. However, there are clear differences in the barriers related to knowledge. Those firms collaborating with TIs rank lack of qualified personnel, and information about technologies and markets as barriers to innovation more highly than firms collaborating with universities, which is in line with their lower levels of internal capabilities.

(Insert Table 8 about here)

Results of the innovative process

This last section of the descriptive results compares the outcomes of innovation activity from both a technological and an organizational viewpoint.

The probability of product or process innovation is similar among both groups of firms, with a slightly higher probability of process innovation for those collaborating with TIs in year 2004 (Table 9). The differences are sharper when we explore the way these innovations are achieved. Firms collaborating

with TIs are more likely to achieve product and process innovations through external collaborations, while firms that collaborate with universities depend to a greater extent on their own efforts.

(Insert Table 9 about here)

Tendency to apply for patents (data only available for 2003) is slightly lower among firms collaborating with TIs (Table 10) as is number of patents by patenting firm. The number of national patents per patenting firm, however, is slightly higher for firms collaborating with TIs. In other words, the main difference is in the registration of European and USA patents.

(Insert Table 10 about here)

From an organizational point of view, there is greater dynamism among firms collaborating with TIs than those collaborating with universities (Table 11) and especially in innovations related to management and strategy.

(Insert Table 11 about here)

4. Econometric results

Here we employ a random effects probit model to observe the influence of various firm characteristics on their probability to cooperate only with TIs or only with universities (Table 13) . The dependent variable is binary and takes the value 1 if the firm has collaborated with a TI and not with a university, and zero otherwise.

We use a set of independent variables to represent the general characteristics and the innovation activity of firms.

First, we consider the following general characteristics. Firm size (SIZE) is the number of employees in the firm. Firm sector is represented by six dummy variables, four of which correspond to the OECD's (2005) classification of manufacturing industries based on technology: high-tech (HIGH TECH), medium-high tech (MEDIUM-HIGH TECH) medium-low tech MEDIUM-LOW TECH), which is used as the control group, and low tech (LOW TECH). We also include two dummies for the service sectors, based on the OECD (OECD 2003) classification: knowledge intensive services (KIS) and the non-knowledge intensive services (NKIS). Finally, we include 17 variables for the region to which the firm belongs. In contrast to the usual regional dummies employed, our database allows us to use the percentage of total R&D staff working in each of the 17 Spanish regions.

Second, we employ three indicators to represent intensity, type and openness of the firm's innovation activity. The intensity of innovation activity is proxied by the percentage of staff dedicated to R&D activities (R&D_STAFF), the type of R&D activity is proxied by the percentage of R&D expenses

oriented to development compared to that oriented to research (TECHDEV) and openness is proxied by the percentage of external R&D expenses over total innovation expenses (EX_R&D).

dF/dx indicates the increment in the probability of collaborating with a TI instead of a university when each variable is incremented by one unit and the rest of variables are fixed in their mean values. A positive ratio suggests that a higher value of the variable is associated with a higher probability of collaboration with a TI than with a university. The P>|z| tests the probability of the coefficient of each variable being equal to zero. If P>|z| is lower than 0.10 we can assume that the variable is significantly different from zero.

The results largely confirm those from the descriptive analysis. Firms collaborating only with universities rather than TIs, are larger, more R&D intensive, and more frequently belong to high tech sectors. Also, the type of R&D performed is different. External R&D and development tasks (the bulk of the budget goes to research) are less important for these firms. Regional location is another factor that is important in explaining the interaction with each type of organization.

(Insert Table 12 about here)

5. Discussion, implications and conclusions

In the literature there is a lack of studies aimed at analysing differences and complementarities among the organizations that make up the knowledge infrastructure, although some authors suggest that they may exist and may be of interest (Smith 1997; Beise and Stahl 1999; Fuellhart and Glasmeier 1999). In our view, there has been insufficient attention paid to some of the heterogeneous support infrastructures that are present in many developed countries, and which usually have strong regional focus. Examples are the Japanese Kosetsushi Centres, the USA Manufacturing Technology Centres, the Italian Real Service Centres and the Spanish TIs.

We investigated the complementarities among these types of organizations and universities, focusing on the Spanish case identifying one form of complementarity among them: the support of different types of firms. We used a recently available database provided by the Spanish Institute of Statistics, which provides panel data for 2003 and 2004 on over 7000 firms. Although this database is biased towards big firms and firms with internal R&D capabilities, our results raise some interesting points for a discussion on the distinct roles played by different support organizations.

We can see that firms collaborating with TIs or universities are very heterogeneous. We attempted to deal, at least partially, with this heterogeneity by analysing both the mean and the median values. To identify the differences in the target firms of each of these groups of organizations more clearly, we defined two groups of firms: those collaborating with TIs but not with universities ("Technology Institutes") and those collaborating with universities but not with TIs ("Universities"). We found that the firms composing these two groups differ in terms of their general characteristics, the nature of their innovation processes and the innovation results obtained. Our results are quite robust because we

analyse data for two years, 2003 and 2004, and the firms constituting the two groups vary substantially from one year to the next. However, the characteristics of the two groups, with some exceptions, remained stable. This shows that the typology of firms supported by one organization or the other is quite well-defined. We also performed a random effects probit model which confirms previous descriptive results.

We found that firms collaborating with TIs are mainly located in regions with a high number of TIs, such as País Vasco, Comunidad Valenciana or Castilla y León. Technology policy in these three regions has clearly prioritized the establishment of these organizations. Thus, it seems that the focus of TIs is regional, which reinforces the results of other studies (Modrego-Rico, Barge-Gil and Núñez-Sánchez 2005; Barge-Gil and Modrego-Rico 2008).

Our results also agree with the findings from previous studies of the bigger size and greater internal capacity of firms collaborating with universities. We were able to investigate this more deeply because of the richer data provided by our database. When compared with firms collaborating with TIs, firms that collaborate with universities spend more money on innovation in both absolute and relative terms (divided by their income). The weight of internal R&D expenditure in total R&D expenses is higher (and the weight of external R&D is lower), they employ more R&D staff and the composition of this staff is oriented more to researchers and less to assistants. R&D activities are focused more on basic and applied R&D and less on development, and the funding for these activities is more likely to come from internal funds. Also, as barrier to innovation, they rank well below factors related to internal knowledge. Thus, it seems that R&D intensity is important for interaction with universities and also the type of R&D, both in terms of the R&D staff and the type of activities they perform. The orientation of a firm's R&D to research and the employment of researchers can facilitate mutual understanding in interaction with academia.

We should point out that although firms collaborating with TIs show lower levels of internal capacity based on the variables described above, they have more internal capabilities than the majority of Spanish firms. The data available do not provide enough information about less technology advanced firms; thus, we can only suggest that TIs are much more focused than universities on those advanced firms with the fewer internal technological capabilities.

On the other hand, it seems that firms collaborating with TIs display more relational capabilities. They spend a higher percentage of their R&D expenses on external R&D, and are more likely to obtain funds from regional administrations and from the European Union. They rank several organizations highly as sources of information, including TIs, customers, consultants and R&D firms, suppliers and competitors. The greater openness of these firms reflects the way they achieve innovations, which depends much more on collaborative activities and much less on in-house activities.

These results provide some intuition about the different profiles of each organization's clients. Firms collaborating with universities have better internal capabilities and seem to assign less importance to external relationships for innovation. Firms collaborating with TIs, however, have fewer internal

capabilities, but are able to employ external resources to develop their innovation processes. This fact could be explained because those firms collaborating with universities perform the most important parts of their innovation activities internally and use their collaboration links for related activities, such as exploration of new knowledge that is far from the market, but not for the direct achievement of new products and processes (Feller, Ailes and Roessner 2002). On the other hand, collaboration with TIs is much more oriented to the development of new products and processes.

In terms of innovation results the differences, although revealing, are not so sharp. Firms collaborating with TIs show similar tendencies to firms collaborating with universities in terms of product innovation and higher tendencies in relation to process innovations. They are also more dynamic from an organizational point of view in the sense that they are more organizationally innovative, especially in terms of management and strategy. This last result can be interpreted as the facility of the "technoeconomic" capabilities of TIs to generate "technoeconomic" changes in firms (Oldsman 1997; van Helleputte and Reid 2004), while universities tend to focus more on the technological or scientific arena.

Overall, these results suggest that, at least in Spain, universities are not so much focused on satisfying the needs of SMEs. In fact, our sample is biased towards firms with internal capabilities and, even among these firms, universities are less likely to assist those with weaker scientific and technological internal resources. Our results show that TIs can play a role for these firms that may become crowded out of university services provision, thus showing the complementarities that exist among these support organizations. Also, TIs seem to be more important to this group of firms than do universities to their clients. This can is explained by the arguments put forward in the literature review about the problems encountered by firms in exploiting the knowledge infrastructure, and the importance of providers in developing firms' "technoeconomic" capabilities in order to overcome these problems.

Our results also shed light on the ongoing debate over the role played by universities in regional development. It is well known that their influence occurs through several channels (Molas-Gallart, Salter, et al. 2002), but recently some authors (MacPherson and Ziolkowski 2005) have emphasized their role as providers of innovation services to firms, following the Triple-Helix approach (Leyesdorff and Etzkowitz 1996; Etzkowitz and Leyesdorff 2000). On the other hand, it has been argued that the main role of universities in territorial development are research activity (although this effect is complex and indirect) (Klevorick, Levin, et al. 1995) and training of graduates (Faggian and McCann 2006). In this sense, our results provide evidence of the third mission of universities; however, this cannot be said to extend to the great majority of the productive sector but rather is focused on a minor portion of firms with some specific characteristics, mainly good internal research capacities. The role of universities in research development would be very constrained if the main channel of influence consisted of being the innovation partner of firms.

However, our study has several limitations. Some are related to the characteristics of the database we drew on which is biased towards (i) big firms, and (ii) R&D performing firms. Thus, we were not able to investigate the role played by TIs when interacting with firms with weaker internal capabilities; they

presumably can play a role for these firms. Also, the questions used in the survey that was the basis of our database follow the Oslo Manual (OECD 1997, 2005) which means we do not have information on issues such as what type of services are the subject of the collaboration, and how many universities and TIs collaborate with each firm, their location and information specific to these relationships.

Nevertheless, we consider that the results of our study contribute to information on the complementarities that exist among the organizations that form the knowledge infrastructure and allow us to better understand the roles of these organizations in regional development, providing information of interest to policy makers in designing initiatives to support firms' innovation processes, to firm managers in making decisions about where to look for external knowledge and to the managers of universities and TIs responsible for defining the strategies of these organizations.

In terms of innovation policy, several authors have claimed that it should be more targeted and use different tools to focus on different groups of firms (Arnold and Thuriaux 1997; Smits and Kuhlmann 2001; Raymond, Mohnen, et al. 2006). Our results also shed some light in this direction, allowing for a better understanding of the roles played by universities and technology institutes. Universities are more focused on big firms or firms with good scientific and technological capabilities, while TIs are more suited to supporting the innovation processes of firms that have some internal technological capabilities, mainly oriented to development tasks.

Finally, we think that our results suggest some directions for future research. First, it would be interesting to widen the analysis to firms with fewer internal technological capabilities, which do not undertake internal R&D activities. Second, we have only analysed the first dimension of complementarity. We suggest that even when the same firm collaborates with universities and technology institutes some degree of complementarity exist between what receives from each of these organizations. Third, we need to know more about the characteristics of the relationship between firms, TIs and universities. How does it start, what type of services are provided and in what volume, how does the relationship evolve, how is the service managed by both sides, etc. As standard surveys do not provide information on these issues, detailed case studies will be very informative. Fourth, we think that it would greatly advance our knowledge to have some direct measure of the impact of these relationships and to tackle the problem of their determinants from a holistic perspective that takes account of the characteristics of the firms, of the knowledge providers, of the relationships among them and of the environment in which the relationships occur.

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Table 1. Firms collaborating only with TIs, only with universities or with both

	2003	2004
Collaborating only with TIs	362	374
Collaborating only with universities	756	544
Collaborating with both types of organization	343	416

Table 2. General characteristics of firms collaborating with TIs and universities

	2003		2004	
	TIs	Universities	TIs	Universities
Economic characteristics				
Income (mean)	29,800,000	165,000,000***	40,500,000	101,000,000**
Income (median)	5,450,458	9,393,370**	7,335,845	8,933,048
Number of employees (mean)	154.57	530.04**	197.03	418.72***
Number of employees (median)	47.00	69.00***	57.00	61,5***
Exports (yes/no)	0.64	0.59*	0.71	0.66
Exports/income (mean)	0.33	0.29*	0.29	0.28
Exports/income (median)	0.26	0.21*	0.20	0.18
Property				
Group (yes/no)	0.36	0.44**	0.41	0.41
Foreign owned (yes/no)	0.11	0.15*	0.10	0.12

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 3. Sector of activity of firms collaborating with TIs and universities

	2003		2004	
	TIs	Universities	TIs	Universities
Manufacturing				
Lowtech sectors (yes/no)	0.25	0.23	0.23	0.24
Low-medium tech sectors (yes/no)	0.30	0.14***	0.36	0.14***
Medium-high tech sectors (yes/no)	0.38	0.40	0.34	0.39
High tech sectors (yes/no)	0.07	0.23***	0.07	0.23***
Service sectors				
Knowledge intensive (yes/no)	0.80	0.70***	0.71	0.69
Non-knowledge intensive (yes/no)	0.20	0.30	0.29	0.31

*** p-value<0.01, ** p-value<0.05, *p-value<0.1 (test)

Table 4. Regional distribution of R&D staff of firms collaborating with TIs and universities

	2003		2004	
	TIs	Universities	TIs	Universities
%Andalucía	2.60	6.52***	1.25	7.75***
%Aragón	2.02	5.85***	2.00	5.16**
%Asturias	3.09	2.18	1.58	2.83
%Baleares	0.28	0.55	0.32	0.48
%Canarias	0.56	0.54	0.63	0.61
%Cantabria	0.28	1.77**	0.32	1.64*
%Castilla y León	7.94	5.80	8.83	4.55
%Castilla La Mancha	0.56	1.73*	0.63	1.20
%Cataluña	9.09	23.02***	12.81	21.94***
% Comunidad Valenciana	19.89	11.87***	15.23	8.89***
%Extremadura	0.56	0.83	0.63	0.26
%Galicia	5.41	7.70	3.15	10.06***
%Madrid	6.34	18.28***	5.37	22.68***
%Murcia	2.53	2.82	0.95	2.47
%Navarra	5.42	3.78	7.07	3.08***
%País Vasco	32.10	5.54***	36.53	5.32***
%Rioja	1.32	1.20	2.71	1.00*
%Ceuta y Melilla	0.00	0.01	0.00	0.00

*** p-value<0.01, ** p-value<0.05, *p-value<0.1 (test)

Table 5. Innovation expenses for firms collaborating with TIs and universities.

	2003		2004	
	TIs	Universities	TIs	Universities
Innovation expenses (mean)	687,000	2,299,038**	657,703	1,968,888***
Median	216,088	306,266***	203,139	274,000**
Innovation expenses/income (mean)	0.17	0.22	0.14	0.28**
Innovation expenses/income (median)	.033	.036	.026	.032
Internal R&D/total innovation expenses (mean)	75.20%	76.81%	67.15%	75.70%***
External R&D/total innovation expenses (mean)	16.47%	12.72%***	22.37%	16.74%***
Other innovation expenses/total innovation expenses (mean)	8.34%	10.47%*	10.48%	7.56%**

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 6. Internal R&D of firms collaborating with TIs and universities

	2003		2004	
	TIs	Universities	TIs	Universities
R&D staff				
R&D staff (mean)	9.62	19.57***	9.41	18.16***
R&D staff (median)	5.00	7.00***	5.00	6.50***
Composition of R&D staff by qualification				
% Researchers	46.59	50.28*	44.49	50.12**
%Technicians	31.86	32.49	33.70	33.44
%Assistants	21.56	17.23**	21.81	16.44***
Internal R&D expenses				
%Basic research	10.50	12.07	9.55	10.65
%Applied research	29.53	44.08***	33.22	41.16***
%Technological development	59.98	43.86***	57.23	48.19***
Funds for internal R&D				
%Own funds	76.84	81.27**	80.06	81.15
%Other Spanish firms' funds	2.28	2.44	1.58	1.45
%Spanish public funds	18.71	13.05***	15.42	13.77
%Foreign funds	2.17	3.24	2.27	2.34

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 7. Importance of sources of information (mean values)[a]

	2004	
External sources of information	TIs	Universities
Internal	1.52	1.47
Suppliers	2.30	2.55***
Customers	2.11	2.37***
Competitors	2.60	2.77**
Consultants or R&D firms	2.58	2.83***
Universities	3.22	1.95***
PROs	3.14	2.99**
TIs	1.96	3.20***
Conferences, markets…	2.51	2.55
Reviews	2.62	2.52
Professional and sectorial associations	2.95	3.00

[a] From 1 (very important) to 5 (non-important)

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 8. Barriers to innovation activity in firms collaborating with TIs and universities (mean values)[a]

	2004	
	TIs	Universities
Cost factors		
Lack of internal funds	2.10	2.17
Lack of external funds	2.11	2.13
Innovation is very expensive	2.05	2.08
Knowledge factors		
Lack of qualified personnel	2.49	2.76***
Lack of information about technology	2.56	2.80***
Lack of information about markets	2.61	2.83***
Difficulties to find partners	2.65	2.74
Market factors		
Market is dominated by established firms	2.41	2.50
Uncertainty about new products	2.18	2.40***
Reasons for not being innovative		
There is no need, we have already innovated	3.45	3.58***
There is no need, no demand for innovations exist	3.47	3.55

[a] From 1 (very important) to 5 (non-important)

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 9. Product and process innovation of firms collaborating with TIs and universities

	2003		2004	
	TIs	Universities	TIs	Universities
Product Innovation				
Product innovation (yes/no)	0.70	0.70	0.80	0.76
Own development (yes/no)	0.80	0.84	0.58	0.61
Development in collaboration (yes/no)	0.51	0.42**	0.40	0.38
External development (yes/no)	0.02	0.04	0.02	0.01
Process Innovation				
Process innovation (yes/no)	0.52	0.53	0.77	0.70**
Own development (yes/no)	0.76	0.81	0.47	0.56**
Development in collaboration (yes/no)	0.50	0.51	0.48	0.37***
External development (yes/no)	0.05	0.07	0.05	0.06

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 10. Industrial and intellectual property in firms collaborating with TIs and universities

	2003	
	TIs	Universities
Industrial and intellectual property		
Request a patent (yes/no)	0.21	0.24
Number of patents		
Number of patents (if patenting)	3.23	3.99
Spanish	2.45	2.21
European	0.69	0.89
USA	0.09	0.33*

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 11. Organizational innovations by firms collaborating with TIs and universities

	2003	
	TIs	Universities
Strategy (yes/no)	0.42	0.37
Management (yes/no)	0.51	0.45**
Organization (yes/no)	0.49	0.45
Marketing (yes/no)	0.32	0.34
Esthetical change (yes/no)	0.43	0.42

*** p-value<0.01, ** p-value<0.05, *p-value<0.1

Table 12. Results of the random effects probit model

Number of obs = 1,899 **Number of groups = 1,450** **Wald test of full model: χ^2 = 273.04***** **Log pseudo-likelihood = -876.35767**				
ctvsuni	dF/dx	Std. Err	z	P>|z|
Size	-.0004977	.0001471	-3.38	0.001
Low-tech	.3194373	.2038964	1.57	0.117
Medium-high-tech	.9283436	.2147018	4.32	0.000
Hightech	-.6475293	.2513671	-2.58	0.010
kis	-.2016077	.2006675	-1.00	0.315
nkis	-.5409369	.2710863	-2.00	0.046
R&D_staff	-.6634763	.2705294	-2.45	0.014
Ex_R&D	.0064218	.0033603	1.91	0.056
Techdev	.0075948	.0016127	4.71	0.000
Region1	-.0020051	.0038337	-0.52	0.601
Region2	-.0021416	.0040501	-0.53	0.597
Region3	.0077843	.0046419	1.68	0.094
Region4	.0112887	.0098314	1.15	0.251
Region5	.0153517	.0080531	1.91	0.057
Region6	-.0089767	.0073879	-1.22	0.224
Region7	.0153417	.0032254	4.76	0.000
Region8	-.0026459	.0068372	-0.39	0.699
Region9	.0031995	.0025233	1.27	0.205
Region10	.0155855	.0026552	5.87	0.000
Region11	.0110635	.0084376	1.31	0.190
Region12	.0011853	.0033181	0.36	0.721
Region14	.0044059	.0046028	0.96	0.338
Region15	.0149534	.00352	4.25	0.000
Region16	.029471	.0027739	10.62	0.000
Region17	.0145196	.0057064	2.54	0.011

[a] Bold characters are used when p-values are lower than 0.10