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Resources exchange patterns with diverse institutional partners within R&D collaborative relationships

Access to reputation and funding

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Abstract

This study addresses the nature of the networks which researchers use to access resources focusing on the nature of network-mediated resource exchanges and the relationship to those network connection strengths. Innovation literature tends to assume that for research collaboration weak ties – allowing loose coupling – are optimal, and it is precisely that notion that we seek to test here. This paper addresses the manner in which relational and institutional traits interact in R&D relationships, and specifically the institutional context and functional characteristics of a tie between two researchers. We use Granovetter's network theory to conceptualise scientific network functioning in R&D collaborative relationships, classifying ties into strong and weak ties. We then analyse how actors' institutional contexts (and their similarity or difference) affect how researchers conduct resources exchanges. We argue ' tie characteristics' can predict different patterns of exchange behaviours depending on partners' institutional affiliations. Our findings stress that institutional affiliation determines which tie characteristics are in the best interest for the access to resources to take place.

Keywords: university-industry interactions, researcher networks, R&D networks, R&D collaboration, tie strength, institutional distance

1. Introduction

One of the main motivations for academic researchers to collaborate in scientific networks is to access resources to their research. This study addresses the nature of the these researcher resource access networks, in particular focusing on the nature of network-mediated resource exchanges and the relationship to those network connection strengths. Innovation literature tends to assume that for research collaboration weak ties – allowing loose coupling – are optimal, and it is precisely that notion that we seek to test here.

Scientific fields can be understood as an endeavour allocating resources efficiently; scientists constantly compete and position/ profile themselves to best access the resources needed for core scientific activities (financial, reputational, and knowledge). However, science is neither a purely competitive transactional arena neither are science resources exchanged purely via top-down hierarchical block grants. Science is inherently uncertain; scientists competing for resources are attempting to raise resources to attempt to do something (create new research results) and can offer no guarantees that they will succeed. Networks provide a means to bridge between pure market and hierarchy resource allocation models, and scientists' social networks have a ex ante signalling function, that a team has the capacity that means it has a good chance of using the resources to create a good 'product' (impactful science).

Thus, understanding science systems requires clearly understanding those networks' significance. Certainly, European policy-makers have placed increasing emphasis on encouraging scientific networks in the European Framework Programmes and Horizon2020. The first consortia emerged in the mid-1980s, and their success laid the basis for making network-building a central European science policy goal. However, sereval issues remain unclear, namely: the dynamics of those networks, and their relationship with scientific content, and the resources exchanged through them.

This paper addresses the manner in which relational and institutional traits interact in R&D relationships, and specifically the institutional context of a tie between two researchers, and the characteristics of that tie. We use Granovetter's network theory to conceptualise scientific network functioning in R&D collaborative relationships, classifying ties into strong and weak ties according to

four dimensions, namely —how long contacts have known each other, the emotional intimacy (or friendship) between the contacts, the degree to which the contacts mutually trust and confide in each other, and the reciprocity in their relationship. Using this definition of strength we firstly characterize the one-to-one exchanges (dyadic relations). We then analyse how the institutional contexts within which the two contacts are embedded (and their similarity or difference) affect the ways researchers conduct resources exchanges. We argue tie characteristics thus defined can predict different patterns exchange behaviours depending on partners' institutional affiliations. Our findings stress that institutional affiliation determines which tie characteristics are in the best interest for the access to resources to take place.

2. Tie strength and academic resource exchange

Scientific collaboration is an intrinsically social process, where individuals, not organizations, are the key actors (Katz & Martin, 1997; Oliver & Liebeskind, 1997; Powell, 1990). The locus of control in scientific collaboration lies primarily with individuals and only secondarily with the organizations with which they are affiliated, particularly when academic institutions are involved (Bozeman & Corley, 2004; Liebeskind, Oliver, Zucker, & Brewer, 1996). Researchers' accumulated know-how and information constitute personal knowledge stocks exploited for both personal and institutional advantage (McFadyen & Cannella Jr, 2004); consequently, R&D collaborations takes place primarily in an interpersonal way (Oliver & Liebeskind, 1997). In contrast to other collaborations, actors involved in scientific collaboration are less guided by formal organisational structures of authority and more dependent on individuals' relationships (Bozeman & Corley, 2004; Powell, 1990; Uzzi, 1996).

The study of R&D networks has mostly been addressed using structural social network analysis approaches using formal mathematical methods to derive network properties including centrality and density (Cantner & Graf, 2006). Such approaches conceptualise individuals' potential control and access to critical resources are in terms of their topological positioning within these networks and regard network properties as being explicable in terms of network architecture (Ahuja et al., 2003). Less attention has been paid to R&D network analysis from a relational perspective, and specifically to considering not just the structure of ties

but their qualities and the effects that this has upon real resources exchanges between them.

Structural approaches have demonstrated a versatile applicability for explaining how networks function in terms of inter-actor distance but do not address the characteristics of actor interconnections. Relationships are not merely functional 'connections' by which actors identify potential future collaborators but also arenas for developing situated learning and knowledge upon which future collaborative research projects can be built (Caniëls et al., 2014). There is clearly a relationship between the quality of the relationships (in terms of a shared knowledge base) and the nature of the business transacted through these relationship (extending the knowledge base through research). Therefore, we argue there is a pressing need to focus on relationship quality, drawing upon Granovetter (1973)'s definition of tie strength.

3. Tie strength & resources access via collaborators from diverse institutional contexts

Granovetter argued that the strength of links within a network can explain resource access (Rowley et al., 2000): this is germane to address our specific research question, namely how does strength of ties between researchers affect the nature of resource exchanges in collaborative research activities. Granovetter defined tie strength around four main characteristics: the amount of time for which the link has existed, the emotional intimacy (or friendship) in the link, mutual confidence (or trust) and reciprocity. These attributes help explain how two social actors mutually interrelate – our question is whether this affects the nature of the resources they exchange. We are not the first to apply Granovetter's framework to innovation and research networks, and with several authors reiterating the importance of tie strength as a determining characteristic of relationship performance (inter alia Rowley et al., 2000; Fromhold-Esebith et al., 2014; Caniëls et al., 2014).

Weak ties are defined as casual acquaintances between social actors (Brass, et al., 1998), involving infrequent interaction (Granovetter, 1973) and lacking substantive friendship, trust or reciprocity. However, weak links can act as "local bridges" to other social circles beyond the individual's immediate environment, helping the actor to discover new resources by connecting actors from different

social circles (Granovetter, 1973; McEvily, and Zaheer, 1999). Weak ties in innovation networks can facilitate brokerage, linking, bridging of structural holes and ultimately strong tie formation (Fritsch, & Kauffeld-Monz, 2010).

However, other types of resources may better be transmitted by strong ties (Uzzi, 1997; Hansen, 1999; Rowley, et al., 2000), based on trust, friendship, reciprocity and frequency of interaction (Krackhardt, 1992; Uzzi, 1997; Brass, et al., 1998; Reagans, and Zuckerman, 2001). Strong ties exists when individuals acquire detailed knowledge about the other's capabilities, attitudes, behaviours and objectives. Trust facilitates cooperation among social actors (Brass, et al., 1998), favouring resources/ information exchange (critical for scientific networks) (Krackhardt, 1992). Interaction frequency provides necessary experience to allow participants to predict (a) which resources the other needs, and (b) how the shared resources would be utilized by the partner (Krackhardt, 1992; Uzzi, 1997). As a result, these strong links provide in-depth and specific knowledge in a particular area of interest for the individuals involved (Rowley, et al., 2000), thereby contributing to knowledge creation and dissemination capabilities.

Nevertheless, collaboration partners may face problems when transferring resources through social relations: actors may have divergent objectives and interests (Bouty, 2000; Wicks & Berman, 2004), or exchange may reveal trading imbalances between partners (Bradach & Eccles, 1989). These difficulties appear to be significantly greater among actors from different institutional contexts; for instance, when they belong to different types of organizations (Powell, 1990; Bouty, 2000). When two individuals interact instrumentally, they have an interpersonal tie but the interaction is affected by their other group (Brass et al., 2004) and institutional affiliations (Leydesdorff, 2000). Individual tie characteristics cannot exclusively explain how actors access resources, by themselves the way resources are accessed by actors: there is a need to consider the role of context, and in particular of institutional affiliation of the partners. The majority of bridge ties between two different institutional collaborators may well start as weak links, yet some may overcome the barriers of institutional distance, becoming strong.

Individuals seeking out resources embedded within other institutional environments have a greater chance of accessing if they can develop a strong tie

with other amenable individuals. This in turn hinges on the degree of affinity between the two actors partly related to the compatibility of their objectives, and the degree to which each approves of the norms of the other's institutional context. This affinity is more difficult and costly to build when actors are dissimilar, despite potentially high future benefits through accessing new resources in other institutional environments (Burt, 1992). This suggests to us that there may be two salient relationships here, with (a) tie strength affecting the magnitude of resources exchanged, and (b) tie strength affect varies according to the institutional distance between partners. We therefore propose the following hypothesis:

H_1: Tie strength is positively related with the access to any type of resources independently of institutional distance between partners.

4. Tie *characteristics* & resources access via collaborators from diverse contexts

Tie characteristics are often reduced to a binary variable (strong or weak) to facilitate representing social networks through their topological architecture. We argue that the impact of tie strength on the reception of resources might however be conditional on different components of tie strength (Silverman & Baum, 2002). The correspondence between tie characteristic and strength depends is at least partly on the interacting agents' institutional contexts. Consequently, ties that have similar characteristics (e.g. frequency, length of contact, and friendship) might potentially have rather different strengths if between people in different organisational contexts: (Keefer & Knack, 2005; Olk & Gibbons, 2010; Zaheer & Zaheer, 2006). Exchange behaviour depends on shared expectations, which are influenced by actors' different institutional environments (Zaheer and Zaheer, 2006). Therefore, different institutional conditions can lead individuals to different exchange expectations. If expectations shape behaviour, then a particular actor may place more weight on one or other relational characteristic depending on their partner's institutional affiliation (something which (Dunn & Jones, 2011) found true for professionals operating in multiple institutional environments. If academics demonstrate such adaptive behaviours when operating in diverse institutional contexts then some tie characteristics may be more salient in accessing resources from firms, while others characteristics may be more salient in exchanges with governmental entities or universities.

Specifically, we argue this can be understood as resources exchange being contingent to the institutional distance between partners. Institutional distance we here define as the level of dissimilarity on each partner's institutional frameworks, the dissimilar habits they exhibit, different cultural norms and traditions, as well as diverse formal incentive regimes (Boschma, 2005). Institutional distance may impact upon actors' relational behaviours via two mechanisms:

(1) Institutional distance affects the accuracy of expectations over the partners' behaviours and intentions: more distance equals less accuracy.

When actors do not share institutional framework, as possible in R&D collaborations between a firm and a university, there may be a difference of cultures, incentive system, objectives and even social and economic roles. It is widely noted that firms first priority around discovery in securing ownership rights whilst academics seek to publish and disseminate Bruneel et al. 2010.

(2) Institutional distance is inversely related with the likelihood of collaborators being direct competitors, diminishing the risk of harmful opportunistic behaviour from the partner: more distance equals less risk.

Within the business of science, partners from different institutional environments are unlikely to be direct competitors as they operate in different contexts (markets) with different roles and may even pursue different kinds of objectives (Powell, 1990). Ties with potential competitors (that is with close institutional partners) carry with them a greater probability (or risk) of opportunistic behaviour (Silverman, and Baum, 2002), exacerbated within research collaborations' technologically dynamic contexts with strong first move advantages (Powell, 1990; Rowley, et al., 2000). Exchanging key resources with competitor-collaborators could expose actors to risk and vulnerability.

Summarising, two forces frame R&D collaborators' resource access:

(1) difficulty generating accurate expectations over partners' behaviour and intentions, and

(2) competitiveness (rivalry) and risk of harmful opportunistic behaviour.

We theorise that the dominant force framing resource exchange will differ depending upon partners' institutional distance. Academia-firms relationship

(institutionally distant partners) behaviour primarily face the former, uncertainty over partner's behaviours: successful resource exchange requires diminishing uncertainty by enhancing learning about partner's operating way and intentions. Conversely, collaborating academics face competitiveness and opportunism, and success relies on developing some sort of control mechanism (formal or informal) discouraging opportunistic behaviour.

To distinguish multiple exchange behaviours, we define tie characteristics following Granovetterian strength, and use Krackhardt's (1992) notion of objectivity, the extent to which particular tie attributes depend on partners' objective/ subjective valuations. We here distinguish (1) objective (2) quasi-objective and (3) subjective characteristics, and argue that that not all tie strength's features will contribute equally to collaborator resource access, which is contingent upon institutional distance between partners.

4.1 Institutional distance, objective characteristics of a tie and resource access

Objective tie characteristics are easily calculated using quantitative measurements, they are not affected by collaborators' subjective valuations, and are consequently symmetrical. Objective indicators do not explicitly imply social norms that actors are forced to follow. This is exemplified by the time actors invest in a relationship, here distinguishing two time attributes: length and interaction frequency. The variable relationship length is calculated as the time elapsed from the creation of the tie to its dissolution or present moment. Interaction frequency is defined as the time dedicated to and/or the number of direct contacts between two actors realize in a certain time period.

These characteristics—length and frequency—are important features of social relationships; interaction over time allows actors to obtain experience necessary for knowing each other's capabilities and behaviours (Krackhardt, 1992, Gulati and Gargiulo, 1999). Knowing each other for longer and contacting more regulrarly allows partners to better predicty which unknown resources the partner may have, and how those resources could be combined with the actor's resources within a relationship (Krackhardt, 1992; Uzzi, 1997). Time invested allows individuals to acquire detailed knowledge about the other's capabilities, attitudes, behaviors and objectives. Time dedicated to the relationship thus provides in-

depth and specific knowledge in a particular area of interest for the individuals involved (Rowley et al., 2000), thereby contributing to knowledge creation and dissemination capabilities.

Actors from different institutional contexts may face greater difficulties in achieving such understanding about their partners and need more information to achieve the same depth of understanding because of specific institutional particularities in each context. A tie's time characteristics become crucial for reducing this institutional distance, promoting mutual understanding and enhancing the exchange of resources between partners. We would therefore expect to find that institutionally-distant partners would invest more time in relationships where there were substantial resource exchanges. Accordingly, we expect to see the following relationships:

> **R_1: the positive relationship between objective characteristics tie and resources access is greater in the case of institutionally distant partners, than more close ones.**

4.2 Institutional distance, quasi-objective characteristics of a tie and resource access

The quasi-objective attributes of a tie are those which are based on a material phenomenon but also on how that is interpreted, and in this case we posit reciprocity, an exchange pattern of mutual benefits between two actors (Gouldner, 1960). Reciprocity is the coequal investment and result perceived by each member in a social relationship, related to individuals' internal standards (Pritchard, 1969). Reciprocity is achieved when the amount and value of goods and services given and received within the relationship are roughly equivalent and are perceived as such by participants (Gouldner, 1960; Uhl & Maslyn 2003; Westphal & Clement, 2008). Reciprocity need not reflect a fairness norm but might also reflect individual self-interest (Blau, 1964; Homans, 1950), seeking to increase the likelihood of future favours (Westphal & Clement, 2008). Reciprocity constitutes an equilibrated and efficient exchange behaviour as individuals intentionally receive what they give enhancing resources exchanges among social actors (Villanueva-Felez et al., 2014).

Reciprocity may vary along two dimensions, namely, intensity and symmetry, both being quasi-objective characteristics as relating perceptions (subjective) of received benefits (objective). Relationship intensity is the strength of the resource

exchange interactions mediated through the relationship, which. Reciprocity symmetry is the degree to which there is a directionality between the flow; actors perceiving that they receive as much as they give is a symmetrical relationship. Conversely, if actors believe that they receive or give far more than vice versa it is a highly asymmetric relationship.

Reciprocal resource exchange is more difficult to achieve when partners belong to different institutional contexts. The relative value of resources may likely differ between institutional spheres, with partners in distinct institutional environments finding it more difficult to agree on the value of the resources given and received. Partners from similar institutional spheres face comparable conditions, and are therefore more likely to reach equivalent assessments of resource value within their exchanges. We likewise believe that reciprocity does not impose any social norm or governance mechanism within the relationship to significantly reduce risk of opportunistic behaviour from competitors.

Both intensity and symmetry will be important for averagely institutionally distant partners, constituting an efficient way to conduct resources exchange when institutional differences do not obstructing collaborations but there is a lack of direct mutual knowledge of institutional context. Hence we expect to find the following relationship

> **R_2: the positive relationship between quasi-objective characteristics and resources access is greatest in the case of partners with an average institutional distance, than more distant or closer ones.**

4.3 Institutional distance, subjective characteristics of a tie and resource access

Subjective tie attributes correspond with more qualitative features in Granovetter's definition—i.e., friendship and trust— and as inherently interpretive aspects rely on individuals' psychological states, making them hard to measure. Friendship entails emotional involvement with another, and hence interpersonal attachment and identification (Blau, 1964; Parsons, 1915). Friendship implies commitment, with individuals making periodic contributions to a relationship without expecting immediate reciprocal benefits. Parties' mutual affection and explicit interest in maintaining the relationship provide sufficient incentives to facilitate mutual benefits (Blau, 1964). An important consequence of friendship is

precisely this sense of duty arising among individuals and intrinsic motivations for being helpful (Blau, 1964; Granovetter, 1983) with friends not shirking mutual social obligations (Parsons, 1915). Friends are bound by "norms of loyalty" diminishing risk of opportunistic behaviour and promoting resources exchange. However, it may promote unequal and inefficient exchanges (Bicchieri & Muldoon, 2011; Clark, 1981; Törnblom & Fredholm, 1984), and a costly R&D collaboration governance mechanism.

Trust, although highly correlated with friendship, is defined as "a psychological state comprising the intention to accept vulnerability based upon positive expectation of the intentions or behaviour of another (Rousseau et al. 1998: 395)". It carries both the perceived likelihood that implicit or explicit agreements will not be infringed upon (Madhok, 1995), and a belief that an exchange partner's behaviour is not exclusively self-interested (Uzzi, 1997). Additionally, trust increases flexibility and tolerance among actors, making it especially important in situations where ambiguity is present and actors contribute their own resources for mutual benefit (Madhok, 1995).

Subjective tie characteristics---friendship and trust---facilitate cooperation among social actors (Brass et al., 1998), as well as resources and information exchanges (Krackhardt, 1992), even between actors from dissimilar institutional environments. Friendship and trust are likewise related to behavioral patterns, and are positively related to the establishment of informal governance mechanisms in relationships (Aulakh et al. 1996). Under the umbrella of these relational elements, actors may forgo explicit contractual arrangements, even if this increases their exposure to risk (Macaulay, 1963). Consequently, reliance on friendship and trust becomes a significant modus operandi in exchanges carrying substantial risk and vulnerability (Coleman, 1990).

Nevertheless, building friendship and trust is not without cost (Madhok, 1995; Zaheer & Zaheer, 2006), involving significant investment of resources for both participants in the relationship, including time and monetary assets (Madhok, 1995). Wicks and Berman (2004) hold that such a costly governance mechanisms is employed only when it is essential: situations with considerable degrees of uncertainty, vulnerability and interdependency (Madhok, 1995; Zaheer & Zaheer, 2006). Ties with potential competitors are more difficult to manage because of the

greater probability (or risk) to behave opportunistically (Silverman, and Baum, 2002), particularly in academic research collaboration with strong first mover advantages, and the substantial disbenefits of being beaten to discovery by an opportunistic collaborator (Powell, 1990; Rowley, et al., 2000).

As said before, it is unlikely that partners from different institutional spheres will be direct competitors as they usually operate in different contexts and may even have different kinds of objectives (Powell, 1990). Therefore, when the contact comes from another institutional context, subjective characteristics may not be such a strong requirement to access resources (lower risk is present), whilst potential competitors conventionally come from the same institutional context. Therefore, we can propose the following relationship:

> **R_3: the positive relationship between subjective characteristics and resources access is greater in the case of institutionally similar partners, than more distant ones.**

We use our three expected relationships as a means for testing our hypothesis H2 and combine them into a single table below.

		Institutional distance		
		Close		Distant
R1: Objective	*Interaction Frequency* *Years in contact*			+ +
R2: Quasi-objective	*Reciprocity Intensity* *Reciprocity Symmetry*		+ +	
R3: Subjective	*Friendship* *Trust*	+ +		

> **H_2: As institutional distance increases between R&D collaborators, academic scientists will tend to rely more on objective tie characteristic to access resources from their collaborators**

5. Methods

5.1 Sample

Testing the hypotheses presented in the preceding section required a context where we could identify individuals scientists who: (1) depend on their access to resources to carry out their work and enhance their academic carriers, and (2) usually interact professionally with other actors from the same and other

institutional context. For these reasons, we selected the field of academic research in nanotechnology. Nano-researchers focus on the development of technologies at the nano-scale (i.e. in the length of approximately 1–100 nm range); they thus require costly equipment such as clean rooms, extremely high-powered microscopes, powerful lasers, etc., that have to be obtained and operated in collaboration with other researchers in academia, industry or government laboratories. Moreover, nanotechnology is an area of research where traditional disciplines merge —material science, molecular biology, chemistry and physics (Stix, 2001)— and where collaboration with other researchers has become essential (Islam & Miyazaki, 2009; Palmberg, Dernis, & Miguet, 2009)

Nevertheless, nanotechnology is a very broad and inclusive term with vague boundaries (Meyer, Morlacchi, Persson, Archambault, & Malsch, 2004). Research in this field includes areas as diverse as medical applications, electronics, robotics, metrology, instrumentation, environment, etc. These areas of knowledge do not necessarily share a direct link, on the contrary, there is considerable cognitive distance between some of them (Meyer & Libaers, 2008), resulting in differing resource requirements and ways of collaborating with other actors.

To deal with such heterogeneity and obtain a controlled and homogeneous sample, we limited this study to the relationships maintained by scientists working in a specific, more homogeneous, sub-field: advanced materials at the nanoscale. The sample for this study included academics at state-funded research centers. We selected 11 research centers that had explicitly stated (via public reports or on their web site) that nano-materials represented their primary research activity; and had published through their website their researchers' names and e-mail address. We identified 866 individuals using this procedure.

5.2 Data Collection

We conducted a web survey among these nano-materials researchers. We had previously piloted a preliminary Spanish and English version of the survey instrument with 10 experts on studies of innovation. The second version of the questionnaire was tested in March 2008 with 6 nanotechnology researchers from Spain (for the Spanish version) and other European countries (for the English version) who were not included in our sample. This second version underwent extensive qualitative pretesting that involved in-depth interviews with the 6

researchers. Each interview was approximately 30 minutes in length. We used feedback from the interviews to refine the wording of the questions, the scales of the answers and the overall presentation of the survey1. The survey was designed and tested in both Spanish and English to address those researchers whose mother tongue was not Spanish.

The survey was launched in April 2008. We also followed a variety of actions to elicit a higher response rate: a multiple contact strategy (prenotice e-mail message, e-mail with questionnaire, follow-ups and reminders), and the personalization of all e-mails and questionnaires (Dillman, 2007). We received 213 responses, which constituted a 25% response rate. From this group, we excluded incomplete cases and those respondents who did not report at least one tie with an external organization2. To reduce the probability of errors arising from the inclusion of researchers working in other nanotechnology sub-areas, we incorporated two qualifying questions to confirm that respondents were working on nano-materials.

Following these filtering stages, the final data set was comprised of 161 individuals: 33 full professors (20.5%), 79 associated scientists (49.1%) and 49 post-doctoral researchers and doctoral students (30.4%). These respondents reported a total of 594 ties with firms, governmental organizations and universities. Table 1 summarizes the relationships reported, by group.

[1] See Annex A for the final version of the survey.
[2] In order to increase the probability of reported contacts from other institutional spheres, we explicitly asked to exclude contacts from their own organization.

TABLE 1: Final Sample

	Full Professors			Associated scientists			PostDocs/Docs			TOTAL		
	n.	%	Nr of ties per individual	n.	%	Nr of ties per individual	n.	%	Nr of ties per individual	n.	%	Nr of ties per individual
Firm	36	23.7	1.09	67	22.8	0.85	25	16.9	0.51	**128**	**21.5**	**0.80**
Governmental organization	38	25.0	1.15	87	29.6	1.10	50	33.8	1.02	**175**	**29.5**	**1.09**
University	78	51.3	2.36	140	51.3	1.77	73	49.3	1.49	**291**	**49.0**	**1.81**
TOTAL	**152**	**100**	**4.61**	**294**	**100**	**3.72**	**148**	**100**	**3.02**	**594**	**100**	**3.69**

5.3 Unit of Analysis and Measures

5.3.1 Unit of analysis

The unit of analysis is the interpersonal relationship between a researcher and his/her main contact at those external and institutionally diverse organizations (firms, governmental entities and universities) collaborating with the scientist. Thus, all the relations analysed are manifestly positive and instrumental. The relevance of this unit of analysis, interpersonal relationship, is well justified throughout the literature. Scholars have found that the locus of control in scientific collaboration lies more on individuals than the organizations they represent, particularly when academic institutions are involved (Bozeman & Corley, 2004; Liebeskind, Oliver, Zucker, & Brewer, 1996). The know-how and information that researchers accumulate over time constitute their own knowledge stocks (McFadyen & Cannella Jr, 2004); consequently, the exchange within R&D collaboration takes place primarily between people and within the context of personal relationships (Oliver & Liebeskind, 1997). Therefore, scientific collaboration is intrinsically a social process, where individuals, not organizations, are the key actors (Katz & Martin, 1997; Oliver & Liebeskind, 1997; Powell, 1990). This implies a complex, and dynamic interaction between the actors involved, less guided by formal structures of authority and more dependent on the relationship among individuals (Bozeman & Corley, 2004; Powell, 1990; Uzzi, 1996).

5.3.2 Dependent variables

We selected two types of resources as dependent variables: reputation—as intangible—and funding and tangible assets—as tangible—. Analysing the acquisition of such different resources from three different institutional partners

(firms, governmental entities and universities) facilitates the discovery of specific exchange modes with enough reliability and validity.

- Reputation represents both an individual and collective's perceptions and beliefs about a particular actor (Hall, 1992; 1993). Such perceptions reflex a complex combination of the characteristics and major personal achievements, behaviours and intentions shown during a period of time that have been directly observed by these third parties and/or known through secondary sources (Zinko, 2007). These perceptions are built according to a set of values and expectations (Emler, 1990) and are based on the information possessed about the individual's past actions (Knoke, 1983; Weigelt y Camerer, 1988).

Reputation is particularly important in contexts characterized by imperfect information, where actors must trust on estimations to make assumptions about other actors' future intentions and behaviours (Weigelt et al., 1988; Fombrun y Shanley, 1990). These estimations come from past interactions and observations and serve as a stable base from where to form opinions about actors and their possible behaviors (Weigelt et al., 1988; Delmestri, Montanari et al., 2005). The acquisition of reputation is particularly important for individual actors, because as their reputation increases, actors become more valuable within different social scenarios (Delmestri et al., 2005), even promoting the emergence of new relations among agents.

- Funding and other tangible assets include access to funding, facilities and equipment to conduct research. Within highly dynamic, technological and competitive fields as is the case of nano-materials, the access to such a key tangible resources maybe crucial for researchers as favors them to adapt their research lines to the new changes in their environment (Powell, 1990; Hansen, 1999; Cross et al., 2004; McFadyen y Cannella Jr, 2005).

We developed and refined the scales of both variables using feedback from the pretest interviews. Initially, a five-point Likert-type response format (from completely agree to completely disagree) was employed to define the scales of both variables. The final version included 4-point agree-disagree scales, with the middle term removed.

5.3.3 Independent variables

The independent variables addressed the objective, quasi-objective and subjective characteristics of the personal ties contained in Granovetter's tie strength definition

Tie strength's objective indicators

The amount of time: interaction frequency and years in contact. The first indicates the frequency of contact between the researcher and his contact. It is an ordinal variable with five categories ranging from weekly to yearly. Years in contact addresses the life span of the relationship. It is an ordinal variable containing five time ranges.

Tie strength's quasi-objective indicators

The level of reciprocity was constructed similar to Friendkin (1980). The base for this was that two items: whether the researcher asked the main contact person for personal and professional advice (item 1) and, conversely, whether the contact person asked the researcher for advice (item 2). The intensity of reciprocity was calculated as the average of these two items: this measurement underlines to what extent both individuals are proactive and their role in the relationship as both advice-seekers and advice-provider. The symmetry of reciprocity was calculated by firstly using the negative modulus of item 1 subtracted from item 2; this variable (which varied from -4 to 0) was then normalised from -0.67 to 0; this normalisation diminishes the asymmetry involved in highly intensity relationships.

Tie strength's subjective indicators

The degree of friendship reflects the emotional intensity of a relationship (Gibbons, 2004). We considered that a friend is an individual who the respondent identifies as such. We asked respondents to indicate to what extent they agreed with the following statement: "I consider this person my friend" (where "this person" refers to the respondent's main contact person at the other organization). The degree of trust refers to the mutual confiding aspect. We asked respondents to specify to what extent they considered his/her main contact person trustworthy.

The scales of all the items contained in these three variables used to measure friendship, trust and reciprocity were set to the five-point Likert-type (from completely agree to completely disagree).

Tie strength

An additional measurement was generated of tie strength, which combines lineally each of the five indicators (communication frequency, years in contact, degree of friendship, degree of trust, and reciprocity) with equal weight, as suggested by Granovetter (1973). Each of these is ranked on a five pointscale.

5.3.4 Control variables

We controlled for aspects that recurrently appear in the literature of innovation studies and university-society relationship. First, the models included attributes of the actors involved in the relationship. On the one hand, respondents' academic rank and type of research were addressed with two dummy variables. The first, distinguishes between full professors, associate scientists and post-doctoral/doctoral researchers. The second classifies academics according to the type of research they conduct: pure fundamental, pure applied and a combination of fundamental and applied research. We also controlled for the contacts' geographical location through another dummy variable which distinguishes if the contacts are regional, national or international. Finally, we controlled for the formal collaborative activities the researchers carried out with their contact organizations. Thus, three dichotomous variables were created to check if both actors were collaborating through 1) joint research or contract research agreements, 2) publications or 3) other activities (consultancy agreements, creation of new facilities/spin-offs and training)

5.4 Analysis Techniques

Non-parametrical statistical techniques were used to analyse our data: Mann–Whitney U-tests, ordered logistic regressions, and bootstrapping.

Mann–Whitney U-tests were used to enrich the descriptive by examining partners' institutional differences in the strength of ties and resources access between respondents and their collaborators (Table 2).

We employed ordered logit regressions (Table 4) to determine the relationship between resources access and tie strength characteristics, using Huber-White sandwich robust estimators to estimate standard errors. These estimators are considered robust because they provide correct standard errors in the presence of violations (e.g. heteroscedasticity) of the assumptions of the model (Long & Freese, 2001). Moreover, working with dyadic data can imply a violation of the assumption that the observations are independent. Since a single researcher can

have relationships with different partners, our respondents were allowed to report multiple relationships. As a result, the error terms in the regression could be affected, given that they can be correlated across observations from the same source. To account for this, we used a cluster option in the estimation to indicate that the observations (relationships) were clustered into individuals. Therefore, the ties reported were possibly correlated within the responses given by one particular individual, but would remain independent between the 161 researchers. The robust cluster technique affects the estimated standard errors and variance-covariance matrix of the estimators, but not the estimated coefficients (Long & Freese, 2001).

Finally, we used the non-parametric bootstrapping procedure to compare differences in the estimated tie characteristics coefficients obtained from the ordered regressions (Angrist and Pischke, 2009). The resulting bootstrapping p-values allow us to compare estimated coefficients from regression models of two different populations. Via this technic we able to check whether the same tie characteristics that explain resources access with different institutional agents result in significantly different outcomes in terms of incremental access to resources (Table 6).

6. Results

The splitting of the sample according to the contacts' institutional affiliation is shown in Table 2. Researchers' respective relationships with agents from three different institutional spheres (university-industry-government) are represented, with a total of 291 ties with universities, 128 ties with firms and 175 ties with governmental agencies. This table also presents the mean of (1) access to reputation and funding, (2) tie strength and, (3) tie characteristics for each group of relationships. Non-parametric tests (U Mann-Whitney) were applied to check whether the values of these elements differ significantly among these three groups.

TABLE 2: Mean Differences of Resources Access and Tie Characteristics– U Mann-Whitney test

	Universities	Sig.	Firms	Sig.	Government Entities	Sig.	Universities
Funding / Other tangible assets Access	2.51	**	2.70	n.s.	2.63	n.s.	2.51
Reputation Access	2.71	**	2.53	†	2.67	n.s.	2.71
TIE STRENGTH	17.73	**	15.43	**	17.23	n.s	17.73

Interaction Frequency	2.82	n.s.	2.73	n.s.	2.83	n.s.	2.82
Years in contact	3.77	**	3.10	**	3.53	*	3.77
Reciprocity Intensity	3.43	**	2.95	**	3.40	n.s.	3.43
Reciprocity Symmetry	-0.05	**	-0.10	†	-0.06	n.s.	-0.05
Friendship	3.59	**	2.94	**	3.46	n.s.	3.59
Trust	4.11	**	3.72	**	4.01	n.s.	4.11
N	291		128		175		291

**p< 0.01. *p< 0.05. †p< 0.1

We assumed three different institutional spheres and three levels of institutional proximity between the researchers and their contacts. The closest institutional actors would be members from universities, followed by those working at governmental agencies. The greatest institutional distance would thus occur with the contacts from firms3.

According to Boschma (2005), institutional proximity is strongly related to social proximity, which is commonly measured by the tie strength between actors. Under this assumption, we expect that all tie strength components shown in Table 3 are significantly lower in the group of relationships with firms than in the rest. We also anticipate that these values are significantly greater in the ties with universities than in the ties with governmental agencies. Moreover, we expect a positive correspondence between the total relationships reported within each group and the institutional proximity, given that interaction tends to occur in a greater proportion among socially close actors (Homans, 1950). The results shown in Table 3 allow us to affirm that three institutional distances do truly exist: the largest group of relationships corresponds to those maintained with university-members (i.e. closer institutional actors), and tie characteristics values are significantly lower with firm-members (i.e. more distant institutional actors). Moreover, we can state that universities and governmental agencies are institutionally closer than governmental agencies and firms. While the values of tie characteristics between governmental agencies and firms are significantly different, those found between governmental agencies and universities are not.

[3] We initially assumed that the respondents belonged to the institutional sphere represented by universities. The targeted centers are (1) university research institutes; (2) joint research centers of the Spanish Research Council (CSIC) and public universities; and (3) CSIC research institutes. Clearly, the researchers from these centers develop professionally mainly under the institutions that apply to universities. Even so, most of them are also directly affected by institutions from the governmental sphere: CSIC is under the Secretary of State for Research, an arm of the Spanish Ministry of Science and Innovation.

Only the variable referring to the years in contact is significantly greater in the relationships with universities.

Table 2 also reveals that access to funding and tangible assets is provided in a greater extent by firms while reputation is acquired through collaborators from universities.

Table 3 displays frequency descriptive statistics of geographical location of researchers contacts, collaboration activities conducted in cooperation and frequencies of the dependent variables—access to reputation and to funding.

TABLE 3: Descriptive Statistics

Variable	Categories	Universities		Governmental entities		Firms	
		n.	%	n.	%	n	%
Geographical Location	Regional	57	19.6	53	30.3	42	32.8
	National	74	25.4	49	28.0	40	31.3
	International	160	55.0	73	41.7	46	35.9
Collaboration activities	Research projects	251	86.3	145	82.9	118	92.2
	Publications	209	71.8	108	61.7	28	21.9
	Other	90	30.9	51	29.1	39	30.5
Funding / Other tangible assets	Completely disagree	63	21.6	26	14.9	21	16.4
	Disagree	57	19.6	39	22.3	15	11.7
	Agree	131	45.0	83	47.4	73	57.0
	Completely agree	40	13.7	27	15.4	19	14.8
Reputation	Completely disagree	17	5.8	12	6.9	11	8.6
	Disagree	90	30.9	56	32.0	53	41.4
	Agree	143	49.1	85	48.6	49	38.3
	Completely agree	41	14.1	22	12.6	15	11.7
TOTAL		**291**	**100%**	**175**	**100%**	**128**	**100%**

Table 4 presents the results of the ordered logit regression models for the access to resources; we constructed to test our hypothesis. We report a total of 12 models to cover all the scenarios: three types of institutional partners and two types of resources, considering the compiled measurement for tie strength, and the unbundled measurement of tie strength into its indicators.

First, and before interpreting the results according to the aforementioned hypotheses, we would like to underline the lack of signification of the control variables addressing "formal collaborating activities". In the light of the models from Table 4, and contrary to commonly expected, the fact of collaborators being engaged in research projects and elaboration of publication is not related in a significant and positive manner to the researchers' perception of accessing to reputation. These two collaboration activities—projects and publications—are certainly fundamental elements of enhancing academics' professional CVs and, thus their reputation as researchers. Also, unexpectedly research projects are significantly related to the access to funding.

TABLE 4: Results of Ordered Logit Regressions on Reputation and Funding (Tangible Assets) Access

	Universities								**Governmental entities**								**Firms**							
	REPUTATION				**FUNDING**				**REPUTATION**				**FUNDING**				**REPUTATION**				**FUNDING**			
	MOD 1		MOD 2		MOD 3		MOD 4		MOD 5		MOD 6		MOD 7		MOD 8		MOD 9		MOD 10		MOD 11		MOD 12	
	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).	Coef.	(Error).
CONTROL																								
Research Type																								
Basic	-0.17	(0.39)	-0.19	(0.39)	-0.48	(0.34)	-0.42	(0.35)	0.09	(0.41)	0.17	(0.42)	-0.42	(0.35)	-0.27	(0.35)	**1.26***	**(0.60)**	**1.13***	**(0.61)**	-0.85	(0.62)	-0.69	(0.66)
Applied	0.12	(0.57)	0.30	(0.63)	**0.93***	**(0.47)**	**1.03***	**(0.57)**	-1.14	(0.89)	-1.11	(0.82)	0.42	(0.64)	0.53	(0.66)	-0.80	(0.64)	-0.64	(0.86)	-0.84	(0.54)	**-1.05†**	**(0.59)**
Academic Rank																								
Professors	**-0.92†**	**(0.53)**	**-1.03†**	**(0.51)**	-0.46	(0.40)	-0.32	(0.42)	-1.06	(0.65)	-0.59	(0.71)	**-1.45****	**(0.50)**	**-1.24***	**(0.55)**	-0.47	(0.77)	-0.17	(0.90)	0.27	(0.67)	0.59	(0.73)
Associate Scientists & equivalent	**-0.90†**	**(0.48)**	**-0.93†**	**(0.46)**	-0.56	(0.38)	-0.43	(0.39)	**-1.20****	**(0.41)**	**-1.14***	**(0.46)**	**-1.10****	**(0.36)**	**-1.13****	**(0.42)**	-0.14	(0.72)	0.12	(0.83)	-0.27	(0.56)	-0.19	(0.60)
Geographical location																								
Regional	0.03	(0.40)	0.12	(0.40)	0.00	(0.36)	0.07	(0.38)	0.21	(0.45)	0.44	(0.45)	0.49	(0.45)	0.65	(0.53)	**-1.21***	**(0.49)**	**-1.09***	**(0.50)**	0.20	(0.35)	0.29	(0.39)
International	0.13	(0.31)	0.12	(0.32)	-0.36	(0.34)	-0.41	(0.35)	0.55	(0.37)	**0.62†**	**(0.34)**	0.58	(0.44)	0.67	(0.46)	0.33	(0.44)	0.34	(0.47)	0.07	(0.46)	0.18	(0.50)
Formal Collaboration Activities																								
Research Projects	0.24	(0.33)	0.27	(0.32)	0.51	(0.40)	0.51	(0.38)	-0.22	(0.45)	-0.37	(0.53)	0.02	(0.33)	-0.07	(0.35)	0.33	(0.61)	0.50	(0.70)	0.61	(0.67)	0.73	(0.84)
Publications	0.34	(0.34)	0.36	(0.34)	0.05	(0.35)	0.01	(0.38)	0.12	(0.45)	0.02	(0.43)	0.06	(0.38)	0.13	(0.40)	0.15	(0.52)	0.39	(0.58)	0.36	(0.49)	0.37	(0.50)
Others	-0.25	(0.36)	-0.27	(0.35)	0.28	(0.40)	0.26	(0.39)	0.53	(0.44)	0.56	(0.45)	0.46	(0.40)	0.51	(0.39)	0.34	(0.43)	0.59	(0.49)	-0.29	(0.40)	-0.27	(0.41)
TIE STRENGTH	**0.25****	**(0.05)**			**0.11***	**(0.04)**			**0.29****	**(0.06)**			**0.13****	**(0.04)**			**0.34****	**(0.07)**			**0.15†**	**(0.08)**		
Objective Indicators																								
Interaction Frequency			0.09	(0.13)			0.01	(0.16)			-0.02	(0.19)			0.06	(0.16)			**0.47***	**(0.19)**			**0.44***	**(0.22)**
Years in contact			**0.29***	**(0.12)**			-0.08	(0.13)			0.06	(0.18)			0.12	(0.15)			-0.21	(0.26)			0.04	(0.18)
Quasi-objective Indicators																								
Reciprocity Intensity			0.33	(0.22)			**0.40***	**(0.18)**			**0.89***	**(0.35)**			**0.97****	**(0.25)**			0.37	(0.27)			-0.11	(0.34)
Reciprocity Symmetry			1.07	(1.72)			**2.92†**	**(1.61)**			**5.25****	**(1.90)**			1.11	(2.08)			**3.13***	**(1.34)**			1.45	(1.64)
Subjective Indicators																								
Friendship			**0.40***	**(0.19)**			0.14	(0.19)			0.41	(0.29)			**-0.43†**	**(0.24)**			0.36	(0.26)			0.12	(0.30)
Trust			0.05	(0.20)			-0.01	(0.15)			0.24	(0.35)			0.15	(0.22)			0.50	(0.30)			0.28	(0.28)
# of observations (relationships)	291		291		291		291		175		175		175		175		128		128		128		128	
# of individuals (cluster)	129		129		129		129		97		97		97		97		68		68		68		68	
Log Pseudolikelihood	-308.3		-306.3		-351.2		-344.6		-174.8		-162.8		-203.8		-196.3		-125.8		-118.8		-137.6		-134.2	
Pseudo R^2	0.08		0.09		0.06		0.08		0.14		0.20		0.08		0.11		0.18		0.22		0.07		0.09	

**p< 0.01. *p< 0.05. †p< 0.1

Table 5 presents in a compiled way a summary of the hypotheses and results from Table 4. It shows the predicted results derive by the hypotheses (represented with a + sign) and only the significant coefficients addressing tie strength and its indicators obtained through the regression models for each group of relationships and the two type of resources.

TABLE 5: Summary Hypotheses and Results

		University		***Government***		***Firms***	
		Reputation	*Funding*	*Reputation*	*Funding*	*Reputation*	*Funding*
HYPOTHESIS 1	*TIE STRENGHT*	+	+	+	+	+	+
RESULTS 1	*TIE STRENGHT*	**0.25****	**0.11***	**0.29****	**0.13****	**0.34****	**0.15**†
	Model (Ordered Logit)	1	3	5	7	9	11
		-		***INSTITUTIONAL DISTANCE***		**+**	
HYPOTHESIS 2	*Objective Indicators*						
	Interaction Frequency					+	+
	Years in contact					+	+
	Quasi-objective Indicators						
	Reciprocity Intensity			+	+		
	Reciprocity Symmetry			+	+		
	Subjective Indicators						
	Friendship	+	+				
	Trust	+	+				
RESULTS 2	*Objective Indicators*						
	Interaction Frequency					**0.47***	**0.44***
	Years in contact	**0.29***					
	Quasi-objective Indicators						
	Reciprocity Intensity		**0.40***	**0.89***	**0.97****		
	Reciprocity Symmetry			**5.25****		**3.13***	
	Subjective Indicators						
	Friendship	**0.40***					
	Trust						
	Model (Ordered Logit)	2	4	6	8	10	12

**p< 0.01. *p< 0.05

Relationship 2 posited that the positive relationship between quasi-objective characteristics (or reciprocity indicators) and resources access is greater in the case of governmental partners, than more distant (firms) or closer (universities) collaborators. We observed in table 5 that in the access to funding from university partners reciprocity intensity is positive and significant. Moreover, reciprocity symmetry also shows a significant coefficient when accessing to reputation from firms. To verify relationship 2 we need to apply an additional statistical technic for checking whether reciprocity coefficients from logistic models referring relationships with governmental collaborators are significantly greater than the rest. Table 6 shows the results of

applying bootstrapping on regression coefficients, revealing significant differences in the two analysed cases; reciprocity has a greater impact in the resources access from average institutional distant partners.

TABLE 6: Results of bootstrapping of reciprocity coefficients differences by collaborators type

RESOURCE - Reciprocity Indicator **Group of relationships**	**Reciprocity coefficient differences by collaborator type**	**Asymptotic significance (one-tailed)**
FUNDING - Reciprocity Intensity Government vs. University	0.57	0.043*
REPUTATION - Reciprocity Symmetry Government vs. Firms	2.12	0.046*

*p< 0.05

Hypothesis 1 posited that strengthen ties is a good strategy to promote the access to resources from collaborators independently their institutional membership. Models 1, 3 5, 7, 9 and 11 verify such hypothesis. With independency of the type of resource and the institutional context, the strength of ties is positively related to the access to these resources.

Hypothesis 2 posited that as institutional proximity (distance) increases between R&D collaborators, academic scientists will tend to rely more on subjective (objective) tie characteristic to access resources from their collaborators. We can observe that for objective indicators of tie strength, interaction frequency is only positive and significant on resources access in the case of relationships with firms, which are undoubtedly the most institutional distant actors from the researchers. However, years in contact appears not to be a significant tie characteristic for the access to any resource, except for the acquisition of reputation from other academic colleagues (closer collaborators). Quasi-objective indicators, represented by reciprocity are dominant in those exchanges carried out with governmental entities. Results reveal that access to resources from this type of collaborator is always related to reciprocity; the two resources analysed rely on reciprocity intensity and reputation also on symmetry. In a lesser extent, symmetrical reciprocity is related with the access to reputation from firms, and reciprocity intensity with the access to funding from universities. However, bootstrapping technics show that reciprocity has a major effect on the access to resources from governmental collaborators.

Finally, it was expected to observe subjective indicators (friendship and trust) to be related only with the access to resources from close institutional partners. Results reveal

that only friendship plays an active role on resources exchanges just with universities and for the access to reputation. The access to funding from close institutional partners is a matter of reciprocity intensity. Remarkable, trust is not related to the access to any of the analysed resources in any case.

Results also show that the tangible and intangible nature of the accessed resource may induce differentiated exchange behaviours. For example, the access to reputation presents a more complex exchange mode; we can observe in Table 5 that when acquiring reputation in all analysed cases, two tie strength indicators are activated. On the contrary, the access to funding relies on just one indicator. For close institutional collaborators, governmental entities and universities, accessing funding and other tangible resources is a matter of reciprocity intensity. That is to say, exchanging great amounts of reciprocal services (in this study, personal and professional advice) favours the shared pool of tangible resources to conduct collaborative research.

7. Discussion

Powell (1990) explicitly holds that when a successful social relationship perdures, the quality of resources accessed is valued more than the quantity. On the contrary, Granovetter (1973) claims that weak ties are more beneficial to actors because this type of ties allows access to greater amounts of non-redundant information. Applying Granovetter's idea to this study, if the development of science relied exclusively on the access to novel information, weak ties would likely be more critical. Given that weak ties need lower costs of maintenance, the network of an individual researcher could be constituted by a larger number of contacts. Consequently, as novel information can be transmitted through weak ties without major hindrances, then increased ties implies increased information quantity, that not necessary quality. But when an activity requires greater coordination efforts and presents greater levels of uncertainty, as is the case in many scientific endeavours, then interaction frequency and reciprocity –in short, strong ties– become more relevant in order to attain agents' goals (Hansen, 1999). As Krackhardt eloquently states it: "change (here: scientific discovery) is the product of strong, affective, and time-honored relationships" (1992:238).

The potential benefits of establishing this type of link -access to dissimilar resources (ties with actors from other institutional circles) coupled with actual use of those resources (thanks to the achieved strength of the link)- are fundamental. Resource achievement is thus a question not only of being connected to sources of differentiated resources, but of using the right channel to access these sources. Burt (1992) considers the possibility of a strong tie evolving into a bridge as rare. However, as the results of this study show, this situation is not necessarily an exceptional one. Initially, it is unlikely researchers will form strong ties with actors with different institutional affiliation; but as academics progress in their professional career and the relationships they forge with actors from diverse institutional environments coalesce, the existence of strong bridge-ties is not extraordinary.

However, as Marsden and Campbell (1984) also found, and as this study corroborates the relative importance of each tie-strength indicator relies on the specific case under study. For example, the study reveals that trust does not affect the access to tangible resources (i.e., funding and tangible assets), which can be explicitly and formally protected by other means. In the context of scientific research, the access to funding is normally formalized through agreements and contracts. In fact, most of the researchers' relationships, especially those with firms, are formalized through research project agreements (see, Table 3). Therefore, in the case of exchange of tangible assets, where the risk of opportunistic behaviour is lower –given that they can be quantified and protected explicitly– trust becomes irrelevant.

The study demonstrates that the tie characteristic upon which the researchers base their access to resources varies depending on the institutional affiliation of their collaborators (see, Tables 4-5). The literature about social relationships assumes an evolution of relations as they consolidate over time. The strengthening of relations is normally reflected by the development of the tie-strength indicators (Bouty, 2000; Coleman, 1990; Granovetter, 1973; Homans, 1950; McFadyen & Cannella Jr, 2004; Putnam, 1993; Racine, 1999; Uzzi, 1996, 1997). However, these studies do not include in their analyses actors' institutional affiliations, nor the underlying dynamics of the access to resources vis-à-vis the tie strength. Our study shows that relationships between researchers and firms are, in general terms, more recent and less developed than those with governmental entities. This stage of early development is characterized by lower

levels of trust, friendship and reciprocity within the relationship (see, Table 2). Therefore, it is likely that this lesser development of the qualitative characteristics of these ties influences researchers' perception of resource acquisition in a way that they only perceive access as the interaction with firms is being realized.

In the case of relationships with nearer actors, the results confirm that the access to resources is in most of the cases reciprocity-based. Actors institutionally close involved in R&D collaborations may find relatively easier to achieve coincidental valuations about the resources they exchange. For this reason it is likely that they systematically base their exchange on reciprocity, which in certain sense we could affirm that constitutes the more efficient and equilibrated mode of exchange within instrumental relations (give and receive tends to equals between partners). The beauty of reciprocity, as Komter (2007) nicely stated, is that combines dichotomies within the same behaviour: generosity and self-interest, altruism and egoism, or freedom and obligation, which are not mutually exclusive, but rather coexist.

At the micro level, this study has demonstrated that any intent of insight on the logics of exchange among R&D collaborators needs to consider jointly all three fundamental elements that constitute social relationships: nodes, ties and resources flows. For example, in this study is possible to observe that collaborators' individual and shared behaviours are being affected by their own and their partners' institutional contexts framing the relationship (nodes characteristic), the nature of the formed linkages between partners (tie strength and its indicators) and the nature of exchanged resources (feature of the resources flow). Together all these elements has the potential to provide with a deep understanding of R&D collaborative relationships.

8. References

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9. Annexes

TABLE 6: Correlation Coefficients[a]

TOTAL (N=594)	Variables	1.	2.	3.	4.	5.	6.	7.	8.
1.	*Funding / Other tangible assets Access*								
2.	*Reputation Access*	0.361**							
3.	Tie strength	0.137**	0.310**						
4.	Interaction Frequency	0.158**	0.180**	0.430**					
5.	Years in contact	0.006	0.155**	0.497**	0.076*				
6.	Reciprocity Intensity	0.189**	0.309**	0.598**	0.258**	0.236**			
7.	Reciprocity Symmetry (RS-nor)	0.046	0.104**	0.025	0.037	0.013	0.076*		
8.	Friendship	0.124**	0.322**	0.732**	0.271**	0.352**	0.509**	0.037	
9.	Trust	0.139**	0.303**	0.631**	0.232**	0.247**	0.415*	0.007	0.557**
FIRMS (N=128)	**Variables**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
1.	*Funding / Other tangible assets Access*								
2.	*Reputation Access*	0.299**							
3.	Tie strength	0.207**	0.310**						
4.	Interaction Frequency	0.216**	0.175*	0.300**					
5.	Years in contact	0.101	0.094	0.377**	-0.085				
6.	Reciprocity Intensity	0.088	0.278**	0.585**	0.085	0.171*			
7.	Reciprocity Symmetry (RS-nor)	0.076	0.144†	-0.008	0.088	0.031	-0.007		
8.	Friendship	0.179*	0.308**	0.688**	0.138†	0.220**	0.477**	0.034	
9.	Trust	0.176*	0.308**	0.615**	0.108	0.188*	0.374**	-0.029	0.533**
GOV (N=175)	**Variables**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
1.	*Funding / Other tangible assets Access*								
2.	*Reputation Access*	0.374**							
3.	Tie strength	0.157**	0.331**						
4.	Interaction Frequency	0.172**	0.210**	0.494**					
5.	Years in contact	0.021	0.145*	0.530**	0.098				
6.	Reciprocity Intensity	0.301**	0.399**	0.621**	0.411**	0.206**			
7.	Reciprocity Symmetry (RS-nor)	0.027	0.141*	-0.029	-0.061	-0.070	0.063		
8.	Friendship	0.113†	0.370**	0.740**	0.336**	0.404**	0.560**	0.009	
9.	Trust	0.157*	0.332**	0.606**	0.290**	0.292**	0.450**	-0.044	0.572**
UNI (N=291)	**Variables**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**
1.	*Funding / Other tangible assets Access*								
2.	*Reputation Access*	0.409**							
3.	Tie strength	0.140**	0.276**						
4.	Interaction Frequency	0.129**	0.161**	0.465**					
5.	Years in contact	-0.010	0.157**	0.493**	0.125*				
6.	Reciprocity Intensity	0.193**	0.244**	0.570**	0.240**	0.239**			
7.	Reciprocity Symmetry (RS-nor)	0.072	0.037	0.029	0.069	0.014	0.092†		
8.	Friendship	0.150**	0.283**	0.727**	0.295**	0.323**	0.477**	0.004	
9.	Trust	0.150**	0.265**	0.600**	0.253**	0.207**	0.382**	0.028	0.583**

[a]Non-parametric Kendall's tau_b correlation coefficients
**p< 0.01. *p< 0.05. †p< 0.1

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