How to identify social ties in innovation partnerships? The case of French science-industry collaborations

Marie Ferru, Michel Grossetti, Marie-Pierre Bès

Abstract

The concept of social network is increasingly used in analysing innovation activities, especially in trying to understand how interorganisational collaborations are embedded in interpersonal relationships.In terms of existing works, there are however problems of measurement and analysis that prevent determining the precise importance of the effects of embeddedness.The purpose of our article is to fill in this gap with a theoretical framework by considering social networks as a form of coordination existing with other, more classic coordination resources like markets and organisations.On this basis, we propose a method for empirically tracking the effects of embedding, and we apply it to more than 200 cases of science-industry collaborations in France. Qualitative and econometric processing of these relational data makes it possible to reaffirm both the significant weight of social networks and the complementary role of coordination resources in putting partners in contact.The networking approach called upon proves to be independent of the characteristics of the partners involved, but it significantly influences the spatial dimension of the partnerships.

JEL:

Key words:embeddedness, social networks, partnerships, coordination, origin, science-industry

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1. Introduction

Collaborations between academic laboratories and industry are often considered major sources of innovation (Mansfield, 1991; Salter et al., 2001; Cohen et al., 2002).Formerly limited to certain fields of research and certain universities (Etzkowitz, 2002), these collaborations have become more common and more widespread over the last thirty years, although they are far from the norm.These collaborations have been the subject of much research from the standpoint of studies on innovation, on the spread of knowledge that occurs (Feldman, 1994; Jolyand Mangematin, 1996; Anselin et *al*., 1997; Agrawal, 2001), the organisational contexts that promote them or not (Bruneel et al., 2010; Carayol, 2003), and the profiles of researchers who pursue them (P. D'esteand Patel, 2007; Owen-Smith and Powell, 2001).

Many authors take an interest in the institutional systems intended to promote these collaborations and assess their performances (Ponomariov and Boardman, 2010; Eom and Lee, 2010). Others focus on the importance of interpersonal relationships (Hagedoorn and Schakenrad, 1994; Shan, Walker and Kogut, 1994; Powell et al., 1996; Zucker et al., 1998).A final category of studies stresses the enhancement of scientific reputations through the awarding of industrial contracts (Godin and Gingras, 2000; Roessner et al., 2010) while underscoring that science is also a "marketplace" to which companies come to look for skills.Some authors use relational data derived from patent data:"a growing number of studies use patent information to apply social networks analysis (…).Some authors link inventors directly by assuming relations between inventors who jointly worked on patents" (Graf and Henning, 2009, p. 1353). These data serve to objectify collaboration networks but do not provide any information that helps understand the construction of collaborations (Giuri and Mariani, 2007).

The studies we present in this work are aimed precisely at filling in this gap, at a theoretical level on the one hand through a conceptual grid for partner networking situations, and at an empirical level on the other through analysis of relational data.

Raising the question of the place of interpersonal relations in science-industry collaborations falls within the theme of embeddedness in the social networks of economic activities (Granovetter, 1985) and more specifically relations between organisations (Eccles, 1981).If we wish to assess the effects of embeddedness, we must have an analytical framework that does not initially postulate the hegemony of networks but rather integrates them into a larger whole.A theoretical exploration of this is therefore essential.We do this by introducing the concept of coordination resources to designate the instruments, systems or organisations that allow networking as a complement to situations coordinated by individual relations.

Furthermore, we need to conceive of an empirical methodology consistent with this theoretical framework that can help us observe the effects of social relationships and economic coordination resources during the phases of partner networking. Hence we introduce an original method that associates qualitative material – obtained through multiple interviews conducted in the spirit of oral history and name-generating methods – and public data on contract partners (for example, location, scientific field).We applied this method to a set of 244 cases of collaboration between academic laboratories and companies in France.A qualitative and quantitative analysis of these relational data will enable us to analyse the embeddedness of science-industry collaborations in social networks.Our empirical work will seek to answer several questions.What is the weight of social networks in generating science-industry collaborations?Is embeddedness in networks explained by certain characteristics of the partners involved in the collaboration?And, finally, do the ways in which partners meet favour the establishment of some science-industry collaborations over others?

We first give an overview of the studies showing the importance of embeddedness in science-industry collaborations (Section 2).We then offer a redefinition of embeddedness in social networks by highlighting the complementary role of coordination resources, and we show the need to develop a methodology for tracking situations of embeddedness (Section 3). We present the empirical work conducted on the basis of this methodology and the building of a relational database (Section 4), and we do a summary of the results from the qualitative and quantitative analysis of our data (Section 5). The final part gives the conclusions from this work (Section 6).

2. Theoretical background:what about embeddedness in SI partnerships?

After briefly reviewing the foundations of the embeddedness concept and its limitations, we introduce the works that apply the embeddedness concept to analysing collaborations for innovation so as to highlight the main lines of questions in this literature.

2.1. Embeddedness approach:insights and limits

In a famous article published in 1985, Mark Granovetter defended the contention that economic activities depend on interpersonal relationships in which the actors are involved and called this dependence embeddedness.This proposition has several implications.On the one hand, economic activity is dependent on more general social structures that are not social groups or categories but networks (Wellman et Berkowitz, 1988). Second, the relevant level of economic action is not that of companies or organisations in general but that of the individual actors and their relationships.Thus, relying on a study by Eccles (1981), Granovetter shows that relations among companies (prime manufacturers and subcontractors in the construction field) are underlain by interpersonal relationships, thereby sketching a “community.”

Granovetter's study opened the way to many new studies in economic sociology (see for example Powell and Smith-Doerr, 1994; Swedberg, 2007), and management (Hoang and Antoncic (2003), for example).The authors sought mainly to determine what types of relationships and network structures are most favourable to economic performance.Some authors developed the concept of embeddedness.For example, Uzzi (1999) utilised the concept to distinguish laying business relations associated with interpersonal relations (which he calls "embedded" ties) from sporadic relations ("arm's-length" ties).The embeddedness theory as advanced by Granovetter was also the subject of a certain number of criticisms (for example, Portes (1998) or Baret et *al*. (2006)).In particular, the concept of embeddedness does not really explain the logic that makes it possible to share without going through interpersonal relations.In his study of the labour market, Granovetter distinguished different ways of getting a job:"personal contacts" (56% of cases), formal means (placement agencies, etc.) (19%), "direct approaches" (spontaneous candidacies) (19%) and miscellaneous other means (6%).Granovetter was especially interested in personal contacts, leaving out the 44% of cases that did not involve social relationships.This premise of the primacy of social networks can be seen as a form of relational reductionism, ignoring the reality of organisations (Grossetti, 2005). Aware of these limitations, some authors have sought to expand the concept of embeddedness.In particular, DiMaggio and Zukin (1990) proposed a classification of the forms of embeddedness in which Granovetter's is just one type ("structural" embeddedness) coexisting with three other types: "cognitive" embeddedness, which designates the cognitive characteristics of humans having the effect of limiting their ability to engage in certain types of reasoning assumed by economic models; "cultural" embeddedness, which refers to shared beliefs in a given collective context; and, finally, "political" embeddedness, designating institutions such as legal frameworks, for example.This classification was taken up and reworked by numerous authors (see for example Beckert, 2010), some of whom included a "geographic" embeddedness (Hess, 2004). These classifications show the value of avoiding reducing the social world to networks,but they also raise significant problems.In fact, while "relational" embeddedness, the mobilisation of interpersonal relations, may give rise to relatively reliable objectivations, the same is not true for the other types, which leads to approximations that are often too crude in empirical studies. We therefore prefer to restrict the concept of embeddedness to the case in which transactions are conducted based on chains of interpersonal relationships and to use another vocabulary for the other cases.

2.2. Over-socialized and over-territorialized conception of embeddedness

Exchanges between companies and academic laboratories have often been studied from the viewpoint of the embeddedness theory.A first series of studies takes individual relationships into account.For example, Walter W. Powell, who worked on biotechnologies in California (Powell and Brantley, 1992), sought to highlight the fact that "behind the formal ties we find informal relations that give them life, support them, and frame their development" (Powell and Smith-Doerr, 1994, p.384). The processes of innovation have also been explained

through methodologies that reveal the innovative networks and their structures, like Gilsing *et al.*(2008), that break down the embeddedness into three dimensions (position in networks, their density and technological distance) or Rost (2010), who obtains data on networks of inventors (strength of ties, structural holes) through questions on their social relationships.Breschi and Catalini (2010) or Lissoni (2010) also focus on the important role of author-inventors in networking between academic circles and innovation circles.Other studies include organisational factors.Kenney and Goe (2004) expand the concept of embeddedness by considering the affiliations of researchers in departments or disciplines as determining their entrepreneurial activities.Ponomariov and Boardman (2010), as well as Eom and Lee (2010), focus instead on the effect of technology transfer centres, which correspond to what we call coordination resources (cf. infra).These studies do not enable us to assess embeddedness in networks of interpersonal relations, since they consider either the networks side or the side of the other coordination resources without attempting to consider both at the same time.The authors ponder the most "effective" configurations of networks or types of systems but cannot assess the share of either.

Furthermore, in works dealing with science-industry collaborations, the concept of embeddedness is at play in a scientific debate on the interpretation of a commonly accepted phenomenon, the existence of effects of spatial proximity.Many works (Acs and Audretsch, 1988; Jaffe, 1989; Audretsch and Feldman, 1994; Mansfield, 1994, and many others) are similar in showing that, other things being equal, collaborations between research laboratories and enterprises are more numerous and more intense within infra-national spaces on the order of employment pools or large urban agglomerations.For many researchers, these proximity effects are explained by the importance taken on by social networks in economic activity and by the fact that these networks are largely local.Existing works generally show that social relationships are formed more easily in the neighbourhood:"The greater the distance, the less contact and support" (Mok et al.,2007, p.434).Some empirical studies (Wellman (1996) on a sample of residents of Toronto, Fischer (1982) on the population of San Francisco and Grossetti (2007) on Toulouse) confirm that personal networks include a large share of local relationships.This is also the case in studies directly inspired by the new economic sociology, like the already cited study by Powell and Brantley, or which explicitly refer to it, like those of Saxenian (1994), or Ferrary and Granovetter (2009) on Silicon Valley.However, there are few studies verifying that the embeddedness of collaborations in social networks promotes the construction of local partnerships.

This brief review of the literature shows the need to specify who is embedded, in what and what is so spatial about it?(Pike et al.,2000).

3. Propositions:rethinking embeddedness for SI partnerships

To add to the works introduced above, we propose an analytical breakdown of the concept

that will distinguish personal relationships from the other coordination resources and will invite the formulation of several hypotheses.We also introduce the construction of a methodological framework making it possible to precisely locate the embeddedness in social networks.

3.1 Hypothesis:towards a multidimensional design of embeddedness

When the actors involved in an interaction are not connected by interpersonal relationship chains, they rely on other cognitive and material resources, which are so many coordination resources. Relying on these resources facilitates the partners' networking in that they reduce the various transactions costs, since they give a framework to the economic action, set rules of interaction and are sources of information considered reliable.This framework supports the credibility of the contractual undertakings IBrousseau, 2000), regulates (opportunistic) behaviours and reduces uncertainty.

These resources may include material systems (directories, Internet sites, newspapers, etc.) as well as organisations or people whose role is to put people in contact (transfer centres, promotion centres, innovation agencies).We consider these coordination resources to be "anything that allows an exchange without going through social-relationship chains," i.e., all systems and institutions have made it possible to put public researchers and their industrial counterparts in touch with one another.

We believe it is necessary to distinguish two subcategories of coordination resources mobilised in the early phases of collaboration:the market resources to which most enterprises and scientists have access (advertisements, conferences, reputation, media, professional-training markets and contracts), and the specific organisational resources of the partners or institutions dedicated to putting laboratories and enterprises in touch with one another (innovation agencies, professional interface institutions, theme days, etc.).

To coordinate with one another, the actors therefore always have a choice between mobilising social relations, calling on market resources, or making use of organisational resources. This distinction between interpersonal relations and coordination resources is in part similar to the classic opposition in neo-institutionalist economics between network and coordination by market or organisation (Powell, 1990). Of course, actors may combine all three categories, but most often we can identify the main form of networking by focusing on the first contact between partners, or by using appropriate methods of narration (cf. infra).Considering the advantages offered by the various forms of networking, we propose to test the following hypothesis:

H1: The networking of innovation partners can be achieved by chains of interpersonal relations as much as by coordination resources (market or organisational).

To our knowledge, few actors have taken an interest in the determining factors of embeddedness:do the characteristics of the actors involved in the collaboration influence the use of social networks?Does the inclusion of the actors in a geographic space (location)

or in a resources space (their scientific field) promote recourse to interpersonal relations or to certain coordination resources?With regard to location, some authors (Detang-Dessandre et al., 2002) have shown the existence of different opportunities in the use of social networks according to the urban or rural character of the location.In the same way, Wahba and Zenou (2005) showed that “denser areas expose people to more contacts” (p. 444), which leads us to formulate a second hypothesis:

H2: The likelihood of recourse to personal relations increases with the density of the actors’ city.

As this is a matter of scientific belonging, no study has established any link between a scientific field and the use of social networks.Hence we can make the following hypothesis:

H3: The researchers’ scientific specialisation has no impact on utilisation of a particular modality of meeting.

Finally, concerning the effects of spatial proximity deriving from utilisation of social networks, very few works take into account both forms of networking, as we indicated previously.Therefore they cannot know whether the embeddedness of collaborations in social networks really promotes the building of local partnerships (relative to coordination resources). Whereas many authors show the local character of social networks (cf. supra), we know that they also consist of non-local relations, and these relations can increasingly be maintained remotely through CIT, and hence “social relation may develop among social actors at different spatial levels” (Lorentzen, 2007, p.11).This leads us to formulate the following two hypotheses:

H4: The nature of the networking influences the geography of the collaborations.

H5: Recourse to social networks does not necessarily lead to the establishment of local partnerships.

3.2. Construction of a method to identify and measure embeddedness

As stated previously, since relational data are unavailable or too limited for understanding the genesis of collaborations, data must be gathered directly from the people involved in the collaborations.From this perspective, it is crucial to have a sufficiently sound method for obtaining them and revealing social networks.

In guides to analysing social networks (Degenne and Forsé, 1999 for example), it is customary to make a distinction between approaches by personal networks, in which relational neighbourhoods are studied around selected actors without making any hypothesis on the relations they might have among them (and without being concerned about these relations), and approaches by complete networks, in which one starts with the existence of resources common to certain actors, and hence likely links among them, in order to select the latter.Analyses of personal networks or complete networks are not

suitable for understanding processes such as the networking of research laboratories and enterprises.Fortunately, there is the relational chains method, famous examples of which are the survey by Milgram on “small worlds” (1967) and that by Granovetter on access to employment (1974). In this method, it is not a matter of analysing static structures but rather of recourse to interpersonal relations in order to access resources.Only relations actually mobilised in concrete actions are taken into account.

Applied to the case of collaborations between academic research and enterprises, this method consists of reconstructing the histories of collaborations.We did this based on in-depth interviews with academic researchers and company heads.[1]The analytical unit is therefore neither the laboratory nor the enterprise but the collaboration between them.A collaboration implies the existence of a contract between the parties, but it may encompass several successive contracts when they involve the same partners.For each collaboration, we try to go back as far as possible by placing it in the career of the researchers or company heads.Hence the history of a collaboration starts well before it led to the signing of a contract.We are especially careful to hear about the genesis of the collaboration, the objective being to identify the modality that initiated the networking of the partners, or in other words to determine how the partners met at the time of their first collaboration.During interviews, we use specific questions that will yield precise information on social relations.When the interviewee cites a person’s name, we ask whether this is someone he or she knew beforehand, in what context this person was met, and for how long the person has been known.After the interviews, the researcher prepares a detailed account of the collaboration and, when necessary to clarify information, he submits this account to the interviewees.This account forms the basis for coding:information relating to networking methods are coded according to the categorisation presented previously (cf. box 1).

Box 1: A collaboration story

Story 022: Collaboration between an automotive manufacturer (located in Ile-de-France) and an engineering science laboratory (L47)

*The partnership (R1) between the two partners is not new (they had collaborated once before)**.** The partners renewed a former partnership for the new research project. The automotive manufacturer wanted to conduct thermo-aerodynamic research on automotive brakes. One of the firm’s scientific directors went to a conference where a researcher explained his work about the item of interest to the firm. “The scientific director was impressed by the results,” explained the researcher. Hence, the manufacturer went to the researcher to discuss and find out if his laboratory might be interested in working with them on this subject. Hence, the contact was made possible by a conference, which is considered a market resource.*

We grouped together the situations we encountered according to the categories of networking procedures proposed earlier.In the first category – mobilisation of interpersonal

[1]The interviews with researchers were conducted face to face (lasting an average of two hours). Complementary interviews were conducted sometimes face to face or by mail (postal or e-mail) but most often by telephone by appointment (lasting an average of 40 to 45 minutes).

relations – contact results from the existence of a prior relational chain linking the people deciding on the collaboration.In the second category – use of operational coordination resources – contact is established under the aegis of an outside organisation that causes, willingly or not, interactions among members of organisations who will subsequently be led to collaborate.Finally, in the third category – mobilisation of market coordination resources – contact results from the initiative of one of the partners who relies on the available information resources (directories, databases, Internet sites) or their meeting at a collective event (conference, trade show), which can be defined as a market coordination resource.

The following table shows the three procedures used for putting two partners in touch with one another, and the situations relating to them.

Table 1: Category of partner networking procedures

Networking procedure	Subcategories in science-industry relations
Personal relations	Professional relations (research colleagues, business colleagues) Nonprofessional relations (family, childhood, associations, friendships) Relations associated with education (students, teachers)
Market resources	Contracts market (contracts with clients, subcontractors, contract-givers) Traineeship market[2] Research market (tenders) Reputation Seminars, conferences, trade shows, fairs (large-scale) Media (press, Internet, publications, *etc*.)
Organisational resources	Projects (competitiveness clusters) Public and semi-public structures (transfer centres) Closed meetings and invitation-only theme days Professional bodies (clubs, technology associations, expert commissions) Relations associated with the organisation of the firm or laboratory

In some cases, laboratories and companies have already collaborated previously and come together again after an interruption.In this case, the new collaboration can be attributed either to the existence of chains of interpersonal ties or to organisational systems deriving from past collaborations.In order to distinguish between the networking modalities, we assess whether the people at the root of the networking can be replaced or not:when the collaboration depends on these people, we consider that it relies on interpersonal relations, whereas if not, when the collaboration experience is largely shared within the organisation, we consider that these are organisational coordination resources.

[2]Some collaborations originate from a student traineeship, obtained in response to an offer put out by the firm to educational institutions.

4. Data and treatments

Building relational data relating to nearly 250 cases of partner networking will allow us to verify our various hypotheses through different statistical and econometric treatments.

4.1. Study corpus and sample

The relational data mobilised in this work were collected through two sets of interviews.Data collection relies on the same method presented earlier and in both cases involves formal collaboration contracts (either under way or completed) between a laboratory and a firm.

The first set of interviews, conducted between 1999 and 2001, involves only the laboratories of the engineering department at the Centre National de la RechercheScientifique (CNRS), France's leading government research agency.The second, conducted between 2007 and 2009, concerns the contracts made by the university laboratories of the University of Poitiers, whether they belong to the CNRS or not.Construction of the overall sample therefore relies on two databases:one covers all the contracts signed by CNRS units with outside bodies between 1986 and 2005 (approximately 33,100 with companies), the other brings together all of the information collected by the Poitiers CVR (Research Development Unit) and relating to contracts signed by Poitier University academics from 2004 to 2007 (about 300 with companies).

With regard to the CVR database, we note that on the laboratory side the engineer and chemical sciences researchers are especially active in terms of industrial research, accounting for more than 70% of the contracts.On the manufacturer side, they are for the most part establishments belonging to the aeronautic and automotive construction sectors or specialising in R&D and engineering.Hence, we find as recurring partners such companies as Snecma, Airbus, Renault, PSA, and major research centres such as Anjou Recherche, Centre de R&D de Veolia.As these are contracts signed by CNRS units, we also note the extreme concentration of the contracts in favour of a few laboratories (50% of the contracts are signed by just 9% of the laboratories) and a few firms (50% of the contracts involve only 3% of companies).The most-represented scientific departments of the CNRS are the chemical sciences (29%), life sciences (20%) and engineering sciences (17%).

We built our sample based on these two databases; more specifically, we selected researchers who held scientific responsibility for contracts and asked them to tell us about several collaboration experiences.Each story collected from a researcher was complemented with interviews of the manufacturer partners or other participants (another researcher, doctoral student funded as part of the collaboration, outside body that was involved, etc.).The investigators conducted 65 initial interviews with the researchers, which we complemented with 129 interviews, (83 with manufacturer partners, 46 with other researchers or participants).We were thus able to reconstruct 244 collaboration histories.

While our sample is representative of both of the mobilised databases, it is not representative of all science-industry collaborations in France.It is however sufficiently

varied in composition so that we can study the correlations between embeddedness in social networks and the characteristics of the laboratories and companies.As we shall see that the share of collaborations initiated by chains of interpersonal relations is not very closely linked to the other characteristics tested, the corpus analysed provides a good estimate of the magnitude of this proportion, which can be likened to an embeddedness rate.

For our sample as a whole, an essential share of the manufacturers involved in the collaborations studied (61%) corresponds to large-scale industrial groups.On the partner laboratory side, they are specialised in engineering sciences (SPI) or information technologies (STI) in 51% and 33% of the cases, respectively.The researchers involved in these collaborations are located in six research clusters.Of the collaborations studied, 130 involve a laboratory in Poitiers, 50 a laboratory in Toulouse, 28 a laboratory in Bordeaux, 21 a laboratory in Grenoble, 22 a laboratory in Montpellier, and 5 a laboratory in Clermont-Ferrand.Thus we can distinguish laboratories located in large centres (Bordeaux, Toulouse, Grenoble, Montpellier) from those located in medium-sized centres (Poitiers, Clermont Ferrand).

Furthermore, based on previous studies (Ferru, 2010; Bès et al., 2010), we know that science-industry collaborations are characterised by repetition of the contracts, that while there is some volatility in the contracts, which are often fleeting, the laboratories have a certain loyalty to their manufacturer partners, especially with large companies (EDF, ELF, RHONE POULENC, SNECMA, ARIBUS, etc.).

With regard to the geography of the collaborations studied, 22% are conducted “locally") (i.e., the research laboratory and the firm are located in the same region), nearly three-fourths of the collaborations are conducted with a French partner outside the region and located primarily in Ile-de-France, this region being involved in nearly 40% of all the collaborations studied and in more than one French collaboration out of two.

4.2 Statistical and econometric treatment of qualitative data

After collecting these qualitative data and ensuring their consistency for both corpuses, we have a set of original variables, shown in the following table.

Table :Data utilised out of an effective total of 244 collaborations

Variable name	Variable meaning	Procedure name	Procedure meaning	[a]N=1	[b]N=0
sc_{domain_k}	Laboratory’s scientific domain	IT	Information technology	80	164
		IS	Engineering sciences	126	118
		$others$	Biological sciences, chemical sciences, humanities and social sciences, physical sciences	38	206
$City_{size_k}$	Size of the laboratory’s city	$large_{cities}$	Toulouse, Bordeaux, Grenoble	122	122
		$medium_{cities}$	Poitiers, Clermont-Ferrand	122	122

LOC_k	Spatial dimension of collaborations	non_{local}	Non-local collaborations	185	59
		$local$	Local collaborations	59	185
$Mod_{contact_k}$	Nature of the networking	soc_{ties}	Social relations	101	143
		$market_{ress}$	Market resource	57	187
		org_{ress}	Organisational resource	77	167
		$undetermined$	undetermined	9	235

[a]N=1 refers to the number of data having the value 1. [b]N=0 refers to the number of data having the value 0.

In order to respond to the three large sets of questions posed previously (cf. 2.3) and in order to complete the qualitative analysis of the descriptive statistics, econometric treatments were done on 235 data (9 networks remaining undetermined as we see in Table 2).

After measuring the weight of embeddedness in social relations relating to recourse to other forms of coordination, independence tests are done between the various networking procedures (interpersonal relations, market resources, organisational resources) and various characteristics of the partners (laboratory's scientific domain and size of the city) and of the partnership (geography of the collaboration).By testing these different relationships of dependence, we can verify whether the characteristics of the actors involved in the collaborations influence recourse to social networks (hypotheses 2 and 3) and whether this embeddedness is significantly associated with local collaborations (hypothesis 4 and 5).

Finally, we create a logistical regression model so as to clarify the links of dependency that prove significant.This enables us to verify the effects of spatial proximity deriving from the use of social relations by indicating whether this network modality has a real impact on the local dimension of collaborations.More specifically, we will test a binary logit.In the model tested, the variable explained corresponds to the local dimension of the collaboration, noted as LOC_k, and the explanatory variables to the various potentially determining factors:the nature of the network modalities and several characteristics of the partners.More specifically, we write the latent variable as LOC_k^* and the associated binary variable as LOC_k which takes the value 1 if the $k^{ième}$ collaboration is established at the local level and the value 0 otherwise.

$$LOC_k = \begin{cases} 1 \; si \;\; LOC_k^* \geq 0 \\ 0 \; sinon \end{cases}$$

With $LOC_k^* = \alpha + Z_k\beta + \mu_k$

Z is the matrix of explanatory variables and β the vector of the associated parameters.

The associated probability is therefore written as:

$$\mathbf{P}(LOC_k = 1|Z_k) = \frac{\exp(\alpha + Z_k\beta)}{1 + \exp(\alpha + Z_k\beta)}$$

We test two versions of this model to measure the influence of network modalities on the local dimension of collaborations at a level more or less disaggregated from personal relations.

5. Results

5.1. The major role of social networks and the complementary role of other coordination resources

The data collected reveal the importance of embeddedness in science-industry collaborations in social networks, with 43% of collaborations having been made possible by an interpersonal relation.The interpersonal relations mobilised to establish collaborations may be of different kinds.The largest share (47% of cases of embeddedness) concerns strictly professional relations among former colleagues or people having worked together on projects.For example, in one of our cases, an engineer with an interprofessional body who became the director of a university laboratory was able to negotiate contracts for his team with his former colleagues, enabling his team to grow quickly.Another frequent (39%) situation is the use of relations deriving from the educational system (professor – former doctoral candidate or former students from the same graduating class).The importance of relations associated with education, and especially with former doctoral students, is well known (Bozeman and Mangematin, 2004). Thus, in our interviews, one researcher states that "*They are a key means,"* while another adds that *"They facilitate contact with the manufacturer, because they are familiar with the laboratory's know-how.*"In one of our histories, for example, an engineer starts work after his training in a company that has regular collaborations with one of the laboratories at his school.After a few years, he changes jobs.Asked by his new employer to set up a central R&D department, he immediately calls on the director of his school's laboratory and negotiates funding with it for a doctoral student:*"I've known the laboratory director for thirty years […], it saves time […], it made it possible to get started more easily."*One researcher explains that one of his collaborations with a foreign firm would not have been possible without this relation associated with education:before this former doctoral student was recruited into the company, the laboratory was already interested in the firm's knowhow and wanted to collaborate with it; it had tried to contact it via the Internet to propose collaborative projects, but the firm had never followed up.Fleming and Frenken (2006), Todling et al. (2008) and Giuliani et al. (2008) have already noted the importance of the recruitment of former doctoral students into companies for the establishment of science-industry collaborations.Finally, there are family or friendship relations with no tie to professional activity, which account for just 14% of cases of embeddedness.In one of our histories, a collaboration between a laboratory and a large firm was established at the initiative of a doctoral student whose father had worked at the firm in question.It was the doctoral

student's father who facilitated his son's and the laboratory's contact with the head of the department that subsequently entered into the collaboration.

The role of embeddedness in social networks is not, however, exclusive:coordination resources, whether market or organisational, seem essential and complementary to the social networks while allowing the networking of the partners in 57% of the collaborations studied, which validates our first hypothesis.Market coordination resources are important (24% of cases).Conferences are an example of this.In one collaboration story, a firm in the automotive sector wanted to conduct thermo-aerodynamic research on braking systems. One of the firm's scientific directors then went to a conference on this topic and there met various university researchers presenting their results.The scientific director was interested in the studies presented by one of the researchers from a Poitier university laboratory.The manufacturer then went to talk to the researcher to find out whether his laboratory might be interested in research work in cooperation with their firm.But many collaborations get established simply because one of the two partners has received information about the other through the media, specialised or otherwise.

Contact between the worlds of science and industry can also be established through a body that is specifically responsible for this kind of work (33% of collaborations were initiated by an organisational resource), like transfer centres or competitive clusters. In one case, the founder of a small firm submitted a problem on controlling the strength of materials to an academic who heads up a regional centre promoting technology transfer.The academic put him in contact with a researcher she knew in the field of the physics of materials.The researcher led them to one of his colleagues, a specialist in non-destructive control, with whom the manufacturer established a collaboration. The role of these transfer centres, however, is less significant than might be expected.Scientific or industrial bodies are a more common organisational resource in partner networking.In one of the cases studied, an academic and an engineer working in an interprofessional body are members of the same topical commission in a governmental body.As a sideline to the commission's activity, they decide to establish a collaboration between their respective teams.Another example involves an engineer with an electrical manufacturing company; put in charge of establishing relations with engineering schools and laboratories, he joined the Arc Électrique club of Électricité de FranceAt a club meeting, he met a researcher with whom he began a collaboration that encompassed three different subjects and continued for some twenty years.

5.2. Independence of network modalities from partner characteristics

By cross-tabulating the three network modalities with the various characteristics of the partners, we find that the weight of embeddedness in social networks remains relatively stable:whatever the scientific field to which the researchers belong, the collaborations were initiated through interpersonal relations in 40 to 50% of the cases.Likewise, whether the researcher is located in a large or small urban centre, the weight of embeddedness in social

networks remains the same.The independence tests allow more rigorous testing of the links between the nature of the embeddedness and the various characteristics of the partners involved in the collaborations.

Table 3: Results of khi² tests

		Market resource	Organisat. resource	Social relation	Total	Results of khi²
$City_{size_k}$	Large Urban Centre	28	43	51	*122*	**X²=0.74 p=0.69 Independence**
	Average urban centre	29	34	50	*113*	
	Total	*57*	*77*	*101*	*235*	
sc_{domain_k}	STI	23	16	36	*75*	**X²=7.50 p=0.11 Independence**
	SPI	28	48	49	*125*	
	Other	6	13	16	*35*	
	Total	*57*	*77*	*101*	*235*	

NB:X² corresponds to the sum of the differences between the theoretical values and the observed values, and p corresponds to the likelihood of an associated error.

These results the especially stable nature of embeddedness of science-industry collaborations in the social relations of the initiators.The geographic or discipline-related characteristics of the partners have no significant impact on the way in which science-industry collaborations begin:the density of the location does not favour recourse to social relations, nor does belonging to a specific scientific field encourage the utilisation of organisational resources.These results confirm the third hypothesis according to which the researchers' scientific specialisation has no impact on utilisation of a particular way of meeting.However, they invalidate the second:the likelihood of recourse to personal relations does not increase significantly with the density of the actors' city.

5. 3 Significant influence of social embeddedness on local collaborations

Now, by cross-tabulating the variables associated with the nature of the networking with those having to do with the geography of the collaborations, we find that the social networks are more frequently utilised when the collaboration is local.Conversely, recourse to coordination resources leads in a great majority of cases to the establishment of a national partnership.The khi² tests confirm part of these results (cf. Table 4) and verify hypothesis 4: the nature of the networking influences the geography of the collaborations.If we break down the networking by interpersonal relations even further, a simple statistical cross-tabulation seems to show that non-professional relations allow the establishment of collaborations at a more restricted spatial scale (cf. Table 5).

Table 4: Tests of independence:network modality and spatial dimension of collaborations

		Organisat. resource	Market resource	Personal relation	*Total*	Results of khi²
LOC_k	Local	16	9	32	*57*	**X²=5.76 p=0.06 Dependence**
	Non-local	61	48	69	*178*	
	Total	77	57	101	*235*	

NB:X^2 corresponds to the sum of the differences between the theoretical values and the observed values, and p corresponds to the likelihood of an associated error.

Table 5: Type of interpersonal relations and local vs non-local collaborations.

Interpersonal relation	local	non-local
Education-linked relation	12	27
Non-professional relation	11	3
Professional relation	9	38
Total	32	69

By definition, the khi² tests do not indicate the meaning of the relationship of dependence between these two variables.We know however that social relations and coordination resources, whether market or organisational, exist before collaborations:they made possible the partners' networking and the formation of the collaboration.This leads us to think that the nature of the networking influences the geography of the partnerships, and to clarify this relationship using a logit-type econometric model in which the explained variable corresponds to the local (vs. non-local) dimension of the collaborations and to the initial network modality.The partners' discipline-related and geographic characteristics are integrated into the model as control variables.The tested model provides several complementary results (summarised in the following table).The first version of the logit reaffirms the positive influence of social embeddedness on the local dimension of collaborations:utilisation of interpersonal relations multiplies the likelihood of establishing a partnership in the region by a factor of 2.5.Organisational resources seem to have no significant influence on the geography of collaborations.The second version of the model, with a finer breakdown of network modalities, makes it possible to further clarify the link between spatial proximity and social relations.Whereas non-professional relations positively and significantly influence intra-regional partnerships – by multiplying the likelihood of establishing collaborations at this spatial scale by a factor of 14 – professional relations do not significantly influence the geography of collaborations.By cross-tabulating the variable associated with the size of the laboratory's location, we note that interprofessional relations are even negatively correlated to the local dimension, which can be explained by the small size of the local labour market.Relations associated with education (reference variable in our model) generate local collaborations, whether in large centres or medium-sized centres, but to a lesser extent than non-professional relations.

Table 6: Result of the binary logit

	Explained variable:	
	1st version	**2nd version**
C	-1.84*** (-3.57)	-1.46*** (-3.47)

Tested variables	$Mod_{contact_k}$	**Market resource**	Ref	-
		Organisat. resource	0.18 (0.37)	-
		Social relation	0.91** (2.10)	-
		Education-linked relation	-	Ref
		Non-professional relation	-	2.64*** (3.78)
		Professional relation	-	-0.14 (-0.32)
Control variables	$City_{size_k}$	**Average urban centre**	-0.77** (-1.87)	-0.77* (-1,79)
		Large Urban Centre	Ref	Ref
	SC_{domain_k}	**SPI**	0.72* (1.67)	0.64 (1.50)
		STI	Ref	Ref
		Other	0,87 (1.55)	0.73 (1.23)
		N	*235*	*101*
		Log-likelihood	*-121.67*	*-115.40*

*Notes:*P<0,1, **P<0,05, ***P<0,00 .t-statistics in brackets*

As these are geographic and scientific characteristics integrated into the model as control variables, we find that location in an average-sized urban centre (Poitiers or Clermont-Ferrand) is a significant disadvantage in terms of local collaborations, as their density does not make it possible to find a potential partner locally. However, this control variable has a far more limited effect than network modalities, its odd ratio being around 2. This being the laboratories' scientific field, it plays only a very negligible role:the SPI variable, significant at the 10% threshold in the first version of the model, is significant not in the second.

The results of this model complement and qualify the literature relating to the geography of social networks.We show that it is not possible to systematically associate social relations with the local dimension of partnerships, which partially invalidates H5.Our work underscores the need to break down social relations according to their precise nature; nonprofessional ties favour the establishment of partnerships that are more geographically circumscribed than relations associated with education or professional activity.

6. Conclusion and discussion

Whereas the embeddedness of science-industry collaborations in social networks appears obvious in many empirical studies, there are very few studies assessing its importance in relation to other forms of coordination.Our article provides the first data to fill in this gap, proposing a redefinition of the concepts – distinguishing social networks from other coordination resources more classic in economics, like market and organisations – and a

sound method for empirically tracking social relations.Application of this method allows the construction of relational data and contributes a new measurement of the role of social networks in science-industry collaborations.We also tested various determinants of this embeddedness in social networks and verified its implications in geographic terms.

A qualitative and quantitative analysis of these data reveal the greater weight of social networks (by making possible the establishment of 43% of collaborations) and the complementary role of market and organisational resources.Embeddedness in social networks varies little as a function of the discipline-related and geographic characteristics of the partners.Finally, our work confirms the existence of a link between embeddedness in social networks and spatial proximity, while clarifying it:only non-professional relations significantly favour local collaborations.

Although the literature on science-industry collaborations focuses primarily on performance indicators, our work shows the need to explore the means and methods of analysing the dynamics of these partnerships by considering the different time frames (genesis, negotiation, start of research theses or projects, exchange of data and results, end and continuation) and their differentiated issues.

Our results should of course be refined using larger and more varied corpuses, in terms both of disciplines and national contexts.However, the similarity of magnitudes of embeddedness with other types of transaction (labour market, for example) suggests that our analysis can probably be generalised.

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