The governance structure in the R&D networks: A comparative approach.

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Abstract

This paper analyses governance structures used to organize partnerships in R&D networks emphasizing the degree of administrative and social factors they embody. Data was obtained from European R&D networks created through Framework Programmes which include a great number of universities, non profit institutions and firms. We argue that governance structures are related to the applicability of technology developed in the network. Findings show that two kinds of networks exist in which administrative structures as well as the openness and cohesion of the R&D network have different relevance in governance structures. This study not only provides a theoretical model to analyse governance structures of these networks but also is useful both for improving the management of networks and for fostering collaboration at an international level.

1. Introduction

R&D alliances as strategic devices have increased substantially during the last decades, encouraged both by companies as well as by public administrations (Hagedoorn *et al*, 2000). R&D networks are considered contractual structures used to organize partnerships in R&D development (Powell and Smith-Doerr, 1994; Ring and Van de Ven, 1992 and 1994). The recognition of organizational structures in R&D networks is an initial condition frequently mentioned in collaborative R&D literature. Ring and Van de Ven (1992) and Teece (1992) affirm that R&D networks are a form of business organization, although there is great dispersion on how to approach the different governance structures of R&D networks.

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With the aim to contribute to the theoretical and empirical analysis of the literature on R&D networks with a new perspective and novel parameters, we will tackle the analysis of governance structures in networks from two points of view. Firstly the more classic view, from a transaction cost approach which states that different governance modes can vary from more structured forms -near to the enterprise- and less structured forms -near to the market- (Williamson, 2002). The objective of this approach is to minimize transaction costs. Secondly from the social capital approach that considers networks as a social form of interrelation (Gulati, 1998; Gulati *et al*., 2000). From this last viewpoint, the governance modes range from highly cohesive and closed networks to opened and sparse networks. The variability of these modes is a function of the exploitation or exploration degree of information. Additionally, in the literature (Brockhoff, 1992; Sakakibara, 1995, 1997; Trott, 1998; Savioz and Sannemann, 1999), activities and objectives of R&D networks are measured by means of applicability which has the attributes of immediacy and acceptability: immediacy in its utilisation and acceptability in the market. Thus the networks undertake different activities, ranging from generic activities centered on basic research to applied activities centered on product development (Teece, 1992; Kotabe and Swan, 1995; Hagedoorn *et al.* 2000).

This study sets out to provide the theoretical basis and empirical evidence to analyse the governance structures in R&D networks. With this aim we have revised the main theoretical and empirical studies on this subject, selecting those factors with the greatest significance in the literature concerned. Hence, a series of key factors relevant to the governance structures have been identified and clustered into two categories: those derived from the transaction cost theory and those derived from considering the R&D networks social structures of ties embedded in the environment. The first category includes some of the features of governance structures to be taken into account from a transaction cost approach (Geringer and Herbert, 1989; Gulati and Singh, 1998; Fdez. de Arroyabe and Arranz, 2000; Artz and Brusch, 2000) both from the viewpoint of structural mechanisms (that is, planning criteria, solving problems and the organisation of activities between partners) and safeguards mechanisms (such as the selection of a partner, the definition of responsibilities or the monitoring and control in the R&D network). The second category, from a social capital approach, comprises the degree of cohesion and the degree of openness of network which are related to the management of information in the network and the technological results obtained ((Robertson and Gatignon, 1998; Gulati, 1998; Rowley *et al.* 2000).

Furthermore, we are interested in the effect that the two groups of factors mentioned above may have on the technological results of R&D networks. Therefore,

taking the relationships between partners in a R&D network as a unit of analysis we will offer single findings for each kind of network.

Once analysed the approaches on governance structures and formulate the hypotheses for further contrast, the sample employed will be described, together with the measures used for each variable involved. Finally, the main results obtained will be shown and discussed, as well the conclusions derived, making reference to future lines of research.

2. Background on governance structures in R&D networks

Gulati (1998), defines governance structures as the formal contractual structures used to organize partnerships in strategic alliances. Williamson (2002) for his part, points out that the objective of governance structures is to infuse order in a relation where potential conflict can arise, and where opportunities to make common gains exist. Williamson (1991) also illustrates that the mode of governance depends on the incentive intensity, the administrative controls and the legal rules regime.

R&D alliances as voluntary arrangements between two or more firms, as points out Gulati (1998), require a suitable governance structure, which has the objectives of solving conflicts (Lorange and Roos, 1992; Mohr and Spekman, 1994), coordinating common tasks (Geringer, 1988, 1991) and distributing results (Ring and Van de Ven, 1994). In sum, the objective is to increase the probability of success of the alliance (Killing, 1983; Harrigan, 1986; Doz, 1988; Ring and Van de Ven, 1992, 1994; Saxton, 1997; Gulati, 1995, 1998).

Governance structures in R&D networks have their own singularities, amply reflected in the literature. Baker (1990) considers that networks are characterized by the achievement of high degrees of flexibility in their structure, based on decentralized planning and control, and the development of lateral links instead of vertical links. Other authors remarked that technological networks are founded on a simple consensus-based structure (Fdez. de Arroyabe and Arranz, 2000; Gulati *et al* 2000; Williamson, 2002). Thus, coordination is generally taken on by the network promoter, whose capacity of decision-taking and supervision is limited, which is subject to the consensus of partners (Nooteboom *et al* 1997; Gulati, 1998). There isn't a marked hierarchical structure, and lateral links serve as the main mechanism for coordination between partners (Gulati, 1995).

Another characteristic that influences governance structures is the dilemma between conflict and cooperation (Gulati, 1998; Williamson, 2002) which arises in networks because they are made up of firms and organizations which have their own objectives, which do not always coincide with the objectives of the network. This circumstance can generate discrepancies among partners (Killing, 1983; Gomes-Casseres, 1987). Marschak (1974) has described this situation based on the concordance of objectives using three levels: team, foundation and coalition, that is ranging from unanimity among partners to discrepancy. This feature of networks makes the inclusion of certain mechanisms necessary (safeguard mechanisms) in governance structures with the objective of mitigating situations of potential conflicts (see, for example, Gulati, 1998). Some authors differentiate between ex-ante and ex-post safeguards mechanisms (Contractor and Lorange, 1988; Hill, 1990; Balakrishnan and Koza, 1993). In the first one we can include the very process of selecting a partner (using criteria such us trust and commitment, previous experiences and son on) and professional skills. Other ex-ante mechanisms appear in the contractual definition of responsibilities among partners in terms of contributions and distribution of benefits. As for the ex-post mechanisms, these are based fundamentally on the definition of control systems of the activities and on the objectives that each partner must achieve. A variety of control mechanisms exists that range from regular reporting to the meetings among partners.

In spite of these common characteristics which exist in technological alliances, we find in the literature a great variety of forms in the governance structure of alliances, as indicated by Powell (1987, 1990). This has generated a line of investigation in which the key explanatory variable in the governance perspective is the choice among alternative modes of governance (Williamson, 2002), which as Gulati (1998) has reformulated, the ex-ante factors for deciding upon the appropriate governance structure.

This question has been widely studied as seen in the literature on transaction costs which explaines the configurations of governance structures emphasizing the degree of structural elements they embody. Williamson (2002) considers the alliance as a contractual form between the market and the firm; in a heuristic way, he states that the choice of a governance structure shifts from the market to the firm. This can be interpreted as the move from simple to complex. Similarly Imai and Itami (1984) consider alliances as hybrid forms of organisation between the market and the firm. For these authors the structure of alliances varies from those forms closer to the market (in which the interaction between agents and the existence of common objectives are

infrequent) to those closer to the firm in which case there is greater the interaction and concordance of objectives.

In general, in the transaction costs approach the explanatory variables for governance structures are *specificity and appropriability* (Robertson and Gatignon, 1998). Here, the objectives of governance structures are minimising transaction costs and opportunistic behaviour, turning them into structural mechanisms and appropriation costs. From this point of view the more the specificity of an alliance the more structured form of governance and the greater the appropriation of technology the greater the safeguard mechanisms.

Nevertheless, the exclusive use of transaction cost approach is considered insufficient to explain the governance form of alliances. Numerous studies (Powell, 1990; Ring and Van de Ven, 1994; Gulati, 1995) show the need to introduce other variables to explain the governance form of alliances. Thus, the degree of interaction between partners, the degree of external openness and the cohesion of the network are variables that intervene in the definition of governance forms.

With this objective, the theoretical point of view of transaction costs has been enriched from other approaches (see Powell, 1990; Zajac and Olsen, 1993). Furthermore Gulati (1998) shows the importance of social structures resulting from prior interaction between partners and suggests that firms select contractual forms for alliances not only on the basis of the activities they include and the related appropriation concerns they anticipate at the outset, but also on the basis of the existence of the social network of prior alliances in which partners may be embedded (Gulati, 1995). Thus, the development of joint R&D projects in a network implies the execution of activities that will create interactions and contacts in the dynamic process of the accomplishment of objectives. Powell (1990) suggests that R&D networks are social networks with a series of interrelated nodes (that comprise institutions and individuals) which permit networks to be defined in terms of structures of ties. These networks of contacts between actors can be an important information source for participants, and therefore, the ties (or the relations between agents) and the information in network acquires a great importance in the definition of governance structures. The strength or weakness of ties will be based on a combination of length of time of the tie itself, emotional intensity, intimacy or mutual confidence, and reciprocal services between the partners of network (Granovetter, 1973).

Many authors have justified the ties between partners as a mechanism of governance structures since strong ties develop a shared understanding of the utility of certain behaviours as a result of discussing opinions in highly socialized relations, which in turn influence their actions (Gulati, 1998; Rowley *et al.* 2000). In addition, these strong ties increase the mutual gains, the reciprocity and the long-term perspectives through a history of interactions (Powell, 1990; Larson, 1992). Therefore, strong ties serve as a part of the social control mechanisms that govern partnership behaviour. According to Granovetter (1973) an actor's collection of weak ties is more likely to be a sparse governance structure reaching divergent regions of the surrounding networks. Networks in the weak tie class require less coordination of activities across partners and therefore less interaction in terms of frequency and depth.

Completing this theoretical approach, Hagedoorn et al. (2000) indicate that technological projects must have external links in order to search for information and knowledge. In this sense, numerous studies emphasise the importance of external sources of knowledge for new product development (Nonaka and Takeuchi, 1995; Peters and Becker, 1998; Teece, 1998). Therefore, we can consider R&D networks as organizational units, which have the objective of developing technological processes via outside interactions. The last argument allows us to define R&D networks as social structures of ties (Granovetter, 1985), embedded in the environment looking for information on the market (Powell and Smith-Doerr, 1994) or technology knowledge (Nonaka and Takeuchi, 1995). The variety of governance forms from this approach is illustrated by Dyer and Nobeoka (2000). These authors show two distinct activities through the case of Toyota's suppliers pointing out that two kinds of networks exist depending on the processing of technological knowledge. The first one network serves to *explore* information with a *great number* of partners*,* and is characterized by *low cohesion* and *weak ties* between partners. Its objective is to obtain technology information. Granovetter (1973), in this sense, argues that weak ties are conduits across which an actor can access novel information. On the contrary, the second one constitutes a *highly cohesive* network with *strong ties* and a *small number of partners* and which has the objective of *exploiting* information in order to, for example, obtain an innovative product. Rowley *et al.* (2000), indicates that strong ties are the appropriate channel to transfer tacit knowledge. Hence, from this approach, we can consider that the networks will vary from the very integrated with strong ties and whose fundamental goal will be to exploit information, to networks which are sparse and open with weak ties, and whose aim is to explore information.

3. Hypotheses

To analyse the variability of governance structures in R&D networks we will analyse two factors: the kind of activity developed and the technological objectives of network. We will draw on technology management field and can observe there that a certain accord exists to classify technological activities in function of their applicability (Brockhoff, 1992; Sakakibara, 1995, 1997; Trott, 1998; Savioz and Sannemann, 1999). Thus, technological activities can be classified as ranging from generic activities with low applicability (such as basic research) to those that generate products with immediate application, such as technology transfer or product development. *Applicability* refers to the *immediacy* or quickness in the use or *acceptance* by the market of a technology. Dosi (1988) points out that basic research involves high levels of uncertainty in terms of expected results and time, so we can consider that basic research is an activity with low applicability.

From this perspective the concept of applicability can be related to the transaction costs view. Thus Brockhoff (1992) links applicability with appropriability and explains that the more general and less applied the research is, the greater the degree of uncertainty will be, the retrieval period of investment and the difficult of appropriation results. Hence, greater applicability corresponds to greater appropriability and therefore to an increased risk of opportunistic behaviour and the need to create safeguard mechanisms. This argument leads to the following hypothesis:

> *Hypothesis 1: The greater the applicability of technology managed in R&D networks the greater the importance of safeguard mechanisms for its governance.*

A second question to treat is how to relate *applicability* with *specificity* of technology (specific asset) which is a capital aspect of transaction cost theory. Technological development in a network involves partners signing a contract which requires specific investments to transact, generating a relationship of mutual dependence (Robertson and Gatignon, 1998). These technological specific assets involve investments in human and physical capital that cannot be redeployed without losing productive value.

A product or technological activity with high applicability has a more restricted alternative use and can be considered a very specific product in its application. In the logic of transaction cost theory greater specificity of assets involves contractual or organizational forms which are very structured and nearer to firm. Therefore, the greater applicability of technological activities developed in the network the more highly structured form of governance. Thus, we can propose:

Hypothesis 2: The greater the applicability of technology managed in R&D networks, the greater the importance of structural mechanisms for its governance.

Conversely, we have seen that networks can be analyzed from a social perspective as social networks. The generation of technological knowledge requires the development of activities of *exploration an exploitation* that, in many cases, can take place simultaneously (March, 1991). This author also points out that *exploration* entails essentially the experimentation of new possibilities and alternatives and, in the same sense, Rowley *et al.* (2000) indicate that experimentation might lead to future innovations and increased profit. *Exploitation*, as March shows, is the refinement and extension of technological competencies to develop current competitive advantages.

As regards this point, we can relate applicability with exploitation. As we have indicated applicability means immediacy in the application of a technology, therefore, we can point out that the higher the applicability of a technology the greater its degree of exploitation. Furthermore, we have seen that the activities of exploitation are developed in highly cohesive networks and, therefore, we can say that networks which develop activities with a high degree of applicability, will be networks based on strong ties among the partners. Hence, we can propose:

Hypothesis 3: The greater the applicability of technology managed in R&D network, the greater the importance of cohesion for its governance.

Equally, we can relate applicability with the exploration activities. As we have pointed out, a characteristic of technological exploration activities is the minor degree of applicability (March, 1991; Rowley *et al*, 2000). These activities are developed through sparse networks, with weak ties among the partners. Consequently, we can

say that technological activities of lower applicability are developed in networks with low cohesion and weak ties among partners and will have numerous external contacts to seek information. Hence we can propose the following hypothesis:

Hypothesis 4: The lower the applicability of the technology managed in R&D network, the greater the importance the degree of openness for its governance.

4. Methodology

4.1. Sample

Having identified the initial conditions and variables, we used data collected from a large sample of joint projects developed into R&D networks to further explore their forms of governance structure.

The data were collected in 1999 on joint projects developed under the III–IV R&D Framework Programme, between the years 1990 and 1998. A sample of 202 institutions was selected for a mail survey. The horizontal character of S&T policy goals has forced us to consider a large number of projects among the different activities marked in III and IV Framework Programmes (information technologies, telematics, industrial and material technologies, environment and climate, socio-economic research, agriculture and fisheries and so on).

During this period, a great number of industrial liaison organisations (ILOs) from different sources (universities, non profit institutions, corporate groups, consortiums of institutions and so on) have participated with high frequency (nearly 90 percent of response rate) in R&D projects.

The distribution of replies by country includes 16 from the EU and EFTA. The basic results of the networks typology show that the most frequent type of partners are universities, industrial partners and research institutes, followed by consultants. The most frequent number of partners ranges from 5 to 7, followed by 3 to 4 and, with a lower frequency, joint projects made up of 8 to 10 partners. In relation to the number of countries that participate in joint projects, the most frequent is 4 to 6.

We pre-tested the survey instrument with a small group of ILO from different countries before sending out the final version. The final questionnaire was then sent to the whole set. A total of 189 valid surveys were returned for a response rate of 93.5 percent.

4.2. Measurement

We have used empirical precedents to develop these measures; we relied on extent literature and fieldwork to select individual items for our scales. Table 1 provides a synthesis of items used to measure each construct from a review of joint research projects which analyse these issues.

Multi-item scales were used to collect data on most of the variables. Simplicity in scoring was sought by using a balanced 5-point Likert-type scale. Basically, each respondent was asked to indicate the extent to which he/she agreed with the given statement or frequency, thus, 1 = strongly disagrees or low frequency and 5 = strongly agrees or high frequency. We pre-tested the survey with a small group of managers from different ILO's before sending out the final version. This helped us modify the suitability of the language used and reject items that were difficult to understand, or in order to avoid repetition.

Table 1. List of items used to measure each theoretical construct

Latent construct	Reference source
A.- Structural Mechanisms	
1.-R&D Planning Criteria 1. Technological and Scientific Knowledge 2. Equal Distribution to all partners and countries 3. "Ad hoc" decisions 4. Requirement of UE institutions	Ouchi and Bolton, 1988; Geringer, 1991; Lorange and Roos, 1991; Bleeke and Erns, 1991; Mytelka, 1991; Fdez.de Arroyabe and Arranz, 2002.
2.- Decision making Opinion in solving problems 1. The opinion of the coordinator 2. The opinion of the partners	
3.-Organisation of activities among partners 1. Each partner develops activities independently 2. Teams to develop activities	
B.-Safeguards Mechanisms 1.-Selection of partner 1. Previous experiences 2. Scientific and technological qualification 3. Requirements of EU programmes 4. Other	Ouchi and Bolton, 1988; Geringen and Hebert, 1989; Ring and Van de Ven, 1994; Mohr and Spekman, 1994; Tidd and Trewhella, 1997; Williamson, 2002.
2.-Definition of responsibilities 1. Contribution of each partner 2. Allocate profits 3. Define tasks	
3.-Monitoring and control of R&D network 1. Partner reports 2. Informal communication 3. Meeting with partners **4.** The project coordinator	
C.-Cohesion Degree 1. Density of contacts 2. Intensity of contacts	Granovetter, 1985; March, 1991 ; Powell and Smith-Doerr, 1994; Dyer and Nobeoka, 2000; Rowley *et al.* (2000).
D.- Openness Degree 1. Frequency of contacts 2. Customer 3. Supplier 4. Competitors 5. Research centres 6. Universities 7. Companies 8. Trade fairs 9. Conferences and workshops 10. Technical and scientific literature 11. Results of public programme 12. Legislation and standards 13. Professional organization	Roberts, 1984; Nonaka and Takeuchi, 1995; Peters and Becker, 1998; Teece, 1998; Hagedoorn *et al*., 2000.

Note: Respondents used a 5-point Likert scale to provide responses on each item, such that "1= strongly disagree or low frequency and 5 = strongly agree or high frequency".

In relation to *independent variables*, the first group referrers to the structural mechanisms which governs R&D networks and is explained from a *transaction cost* perspective. The first variable is the degree of structure which can vary depending upon the similarity of the network structural elements to the market or the firm. The mechanisms used are derived from the need *to plan, decide and organize* the activities to be developed (see Geringer, 1991; Lorange and Roos, 1991 or Bleeke and Erns, 1991). In relation to the planning and organization of network, diverse criteria are sited in the literature (Ouchi and Bolton, 1988; Mytelka, 1991; Fdez.de Arroyabe and Arranz, 2002). The first is linked to the equilibrium among partners and in European transnational projects also includes the country factor, which seeks a certain equilibrium in the distribution of tasks. The second criteria considers the scientific and technological specialization of the partners. The last one refers to the special requirements of the project, mainly in sponsored projects. Regarding decision making, the specific literature shows that two centres of decision making exist: the coordinator of network and the consensus between partners. The second group of independent variables is related to safeguard mechanisms which govern R&D networks in order to avoid opportunistic behaviour (Ouchi and Bolton, 1988; Tidd and Trewhella, 1997; Williamson, 2002). The specific literature on networks asserts that the selection of a partner, based on previous experiences and confidence serve as important factors to minimize opportunistic behaviour. Furthermore, the definition of responsibilities (both in the inputs and the sharing of benefits as well as in the definition of tasks) and the control mechanisms (reports and meetings among partners, the role of coordinator and so on) are frequently used as safeguard mechanisms (Geringen and Hebert, 1989; Ring and Van de Ven, 1994; Mohr and Spekman, 1994).

As we have indicated in the literature review, the point of view of transaction cost is not the only factor that can explain the governance forms of networks. In this respect we will introduce a set of variables, which following the approach from social capital, help us to understand the form of governance chosen in the network. From this approach the variables used refer to the degree of cohesion in the interaction among partners and to the degree of openness of the network.

As Rowley *et al.* (2000) indicate, to measure the *degree of cohesion* of a network, the intensity and density of contacts among the partners must be born in mind. Contractor and Lorange (1988) point out that the greater the intensity and density of contacts the greater the cohesion of the network. Conversely hand the *degree of openness* is determined by the frequency and the diversity of external contacts of the

network. Thus, the greater the frequency and the diversity of contacts the more open the network is to the exterior. Following Roberts (1984) we can differentiate among external contacts with suppliers, clients and competitors, institutions, documental sources and so on.

As relates to the *dependent variables*, these attempt to analyse the activities developed in the R&D network. As we have indicated, Brockhoff (1992), Sakakibara (1995, 1997) and Trott (1998) classify technological activities in function of their *applicability*: from pre competitive or generic activities, such as basic research, to very applied activities designed to obtain commercial products –through an innovative process, for example– and developing activities intended to the transfer of technology. To determine this factor, we propose the analysis of two key variables: the first related to the *activities* developed in the network and the second related to the kind of *objectives* pursued.

Table 2. Activities and objectives in function of their applicability

Applicability	**Activities**	**Objectives**
Higher ↓ Lower	▪ Product Development ▪ Applied Research ▪ Pre-commercial applied research ▪ Basic Research	▪ New Products ▪ Patents ▪ Training ▪ Resources and research databases ▪ Scientific publications

5. Results

In the first stage, we proceeded to treat the variables, homogenizing and simplifying them, with the aim of obtaining a constructs or factors that represent the governance form of the network. In the second stage, we will apply the causal model, which relates the factors that define the governance form to the applicability degree of the technology managed in the network, both refer to the activity developed and to the objectives pursued. Table 3 shows the group of different variables that were obtained through a factorial analysis.

Table 3. Descriptive statistics of governance forms

Latent construct	Description value Mean	Factorial Analysis Weight	Reliability Analysis α Cronbach
A.- Structure Factor.			0.813
1.- R&D Planning Criteria			
1. Technological and Scientific Knowledge	2.5	.756	
2. Equal Distribution to all partners and countries	3.6	.837	
3. "Ad hoc" decisions	2.1	.644	
4. Requirement of UE institutions	3.0	.785	
2.- Opinion in solving problems			
1. The opinion of the coordinator	3.7	.811	
2. The opinion of the partners.	4.1	.823	
3.- Organisation of activities with partners			
1. Each partner develops activities independently	3.4	.530	
2. Teams to develop activities	2.5	.372	
B.-Safeguard Factor.			0.732
1.- Selection of partner			
1. Previous experiences	4.0	.794	
2. Scientific and technological qualification	3.3	.422	
3. Requirements of EU programmes	3.7	.617	
4. Other	1.2	.253	
2.-Definition of responsibilities			
1. Contribution of each partner	3.9	.811	
2. Allocate profits	3.8	.809	
3. Define tasks	3.3	.790	
		.321	
3.-Monitoring and control of R&D network			
1. Partner reports	2.7	.450	
2. Informal communication	3.3	.547	
3. Meeting with partners		.765	
4. The project coordinator	4.1	.201	
	3.2		
C.-Cohesion Factor.			0.741
1. Density of contacts	3.2	.798	
2. Intensity of contacts	4.3	.840	
D.- Openness Factor.			0.680
1. Frequency of contacts	2.0	.673	
2. Customer	2.2	.477	
3. Supplier	3.5	.545	
4. Competitors	1.6	.273	
5. Research centres	2.7	.331	
6. Universities	2.9	.460	
7. Companies	2.8	.495	
8. Trade fairs	2.9	.584	
9. Conferences and workshops	1.3	.380	
10. Technical and scientific literature	2.0	.510	
11. Results of public programme	1.8	.335	
12. Legislation and standards	1.4	.297	
13. Professional organization	1.2	.253	

To assess reliability we computed Cronbach alphas for each multiple scale item and found this to be well above the cut-of value of 0.7 in each case (Nunnally, 1978). Table 4 provides the correlation matrix of the key variables (Bagozzi and Yi, 1988). We get satisfactory results for validity and reliability from factors. Thus, we can accept the validity of factors.

Table 4. Correlation matrix between factors

	Structure	Safeguard	Cohesions	Openness
Structure	1.000	0.189	0.197	0.053
Safeguard		1.000	0.064	0.017
Cohesion			1.000	0.058
Openness				1.000

Causal Analysis

To examine the relationships among the applicability of technologies developed in a network and the forms of governance, we constructed an OLS regression model.

The OSL regression model (Table 5 and 6) examines the influence that factors of governance (Structural mechanisms, safeguard mechanisms, cohesion and openness degree) have both on technological activities and on the objectives of projects.

Table 5. Technological activities of the network (OLS regression model).

Variable	Beta coefficient			
	Basic Research	Pre-commercial applied research	Applied Research	Product development
(Constant)	.056	-.042	.112	.099
STRUCTURE	-.034	.053	.374	.510
SAFEGUARD	-.116	-.048	.271	.358
COHESION	.003	.022	.311	.490
OPENNESS	.435	.489	.032	.045
R2 (adjusted)	.415	.510	.691	.580
			N=189	

Table 6. Objectives of network (OLS regression model).

Variable	Beta coefficient				
	Patents	Training	New products	Resources and research databases	Scientific publications
(Constant)	.024	-.005	.198	-.013	.070
STRUCTURE	.332	.107	.523	-.053	.072
SAFEGUARD	.210	.065	.302	-.242	-.059
COHESION	.454	.078	.609	.097	.119
OPENNESS	.087	.173	.076	.007	.133
R2 (adjusted)	.506	.652	.540	.243	.328
			N=189		

6. Discussion

As it can be observed, results of the parameters corroborate that the *structural factor* has a great importance on product development (.510) and applied research (.374) when we analyse the activities developed in the R&D network. Furthermore, structural factor has a great significance when the objective of network is the development of new products (.523). Regarding the evolution of *safeguard mechanism* factor, we must point out as in the case of the structural factor, it has greater weight in the case of applied research (.271) as well as in product development (.358). As regards the objectives of network, these mechanisms gain relevance if the goal is to develop new products (.302) and in the case of obtaining patents (.210). In our model, the cohesion and openness factors have been introduced in order to analyse both the density and intensity of contacts and the frequency and kind of external contacts. Hence, it can be affirmed that *openness factors* have great importance in the case of basic research (.435) and pre-commercial applied research (.489) as well as when the objectives are training (.173) and scientific publications (.133). As regards the *cohesion factor* has a great importance in technological activities directed to product development (.490) and applied research (.311) as well as when the objectives are to achieve new products (.609) and patents (.454).

All these results have allowed us to contrast the hypotheses stated in this study and to confirm them positively. The first hypothesis or link between applicability and safeguard mechanisms is confirmed as much in the kind of activities as in the objectives of network. Applied research and product development are activities with high a high degree of applicability and their evolvement through R&D networks can lead to opportunistic behaviours among the agents taking part. From the view point of

objectives, safeguard mechanisms are established due to the fact that new products and patents have immediate applicability. In the case of activities with low applicability such as basic research or pre-commercial applied research and in the case of objectives related to the diffusion of knowledge such as training, scientific publications and research databases, no direct relationship has been found.

Moreover, the structural factor is significant again both in the case of activities with high applicability (product development and applied research) and in the case in which the objectives of the network can be implemented immediately, such as new products or patents. Therefore, regarding hypothesis 2, results allow us to accept the relationship between the applicability of technology and the degree of structural mechanisms in the network. If focusing on the activities with low applicability –such as basic research– and on less applied objectives (such as generating scientific publications or resources and data base) the structure mechanisms do not seem to have importance. These findings are consistent with transaction cost theory in which greater applicability tends to create contractual structures, as is marked by Williamson (2002), designed to manage the technology in the network. On the contrary, when the applicability of technology is lesser the structure has a minor relevance.

With respect to *cohesion factor*, our findings show that in the case of technological activities developed in the network, this factor is very important regarding pre-commercial applied research, applied research and when the activity undertaken is product development. Likewise, we can observe that cohesion has minor importance in the case of basic research. On the other hand when analyse the network objectives, we found that cohesion inside the network has a great weight if the purpose is to develop new products or to obtain patents or licenses. Therefore, the cohesion factor has great importance in more applied activities and objectives, in which exploiting the information is a key question. Hence, we can confirm hypothesis 3, which states that applicability has a positive influence on the cohesion of a network.

As regards on external openness factors, we find that these have great importance when the activities developed in the network refer to basic research. As for the objectives of network, external sources are shown to be more relevant both in scientific publications and research data bases and in the case of training. So network openness has great importance when applicability is lesser, that is, when the aim of R&D network is to spread knowledge or is designed to gather information. Hence, as regards hypothesis 4, based on own results we find a relationship between the degree of applicability and the degree of openness of the network.

Our results confirm that the applicability of technology has an influence both on administrative structures as well as on the openness and cohesion of R&D networks. We show that two kinds of networks exist. The first category of networks which have the objective of developing more applied activities or, as March (1991) points out, carrying out exploitation activities which lead to a competitive improvement of products or services. In this first category, governance form is based on a higher cohesion characterized by high density and intensity of contacts among the partners of network and a structural framework designed to execute its activity. Thus, this first category uses mechanisms of planning and organization in its governance form and the decision making is carried out by the consensus between the coordinator and the partners. Furthermore this type of network adopts a series of safeguard mechanisms mainly based on the selection of partners, the definition of responsibilities and the putting into practice of monitoring and control mechanisms. In addition, the opening degree and external contacts are minimal.

The second category are networks designed to develop lesser applied activities, or in March's terminology, to perform exploration activities. Their governance form is characterized by the low importance of administrative factors and safeguard mechanisms and the primary goal is capturing information (March, 1991; Rowley *et al.*, 2000). To undertake these activities of exploration, external contacts and a higher openness degree have a great importance while the cohesion factor –in terms of density and intensity of contacts– have low significance.

7. Conclusions

Given the limited number of studies which provide empirical evidence regarding governance structures in R&D networks, the purpose of this paper has been to add empirical evidence which allows us to characterize the forms of governance in terms of the applicability of the technology managed in the networks. To do so, a set of factors were selected and grouped into two categories. Structural or administrative factors selected, basic for the analysis of governance forms, have been planning criteria, decision making and organization of activities. The social factors chosen were cohesion and openness degree of network. Next, they were tested in a sample of European R&D networks where firms and research organizations were involved during the period 1990- 1999. In summary, this study contributes by the fact that it integrates the factors which influence governance structures in networks in two groups

(administrative and social); the unit of analysis, being the project the core of R&D network; and the selection of a sample with very limited previous study.

Unlike other previous studies, where research has been limited to the analysis of governance structures from a single approach, our study analyses the forms of governance from the two main approaches that explain the dynamics and implications of network management. The results lead us to observe that the applicability of R&D developed in the network is the factor that determines its governance form. These results constitute an empirical contribution to the study of the management of R&D networks. Moreover, we have obtained a series of conclusions and implications that can be of great use, both in the academic world and in the management of R&D networks. First of all, we have elaborated and tested a theoretical model that identifies the determining factors of governance structures in R&D networks. Factor grouping into two categories (administrative and social) makes a novel contribution to the study of the governance of R&D networks as it provides a way to integrate previous studies. In this sense, we find that our model allows the heterogeneity of that specialized literature to be overcome. Equally important is the unit of analysis chosen. We have collected data from research organizations that operate in the context of Framework Programs fostered by the European Union. Results reveal the importance that technological objectives pursued and technological activities developed have on the performance of network both from am administrative aspect and as regards the cohesion and openness degree among partners. These aspects give us a more comprehensive and detailed perspective of this kind of networks and can be considered an original and relevant contribution due to the lack of precedents and the importance of technological cooperation for the development of European S&T Policy.

To conclude, it must be said that this study represents a starting point for future research studies intended to widen theoretical and empirical evidence about the performance of R&D networks. As a research agenda, we suggest the undertaking of an in-depth analysis of the factors identified for governance structures, as well as the identification of new factors that might in some way have influence on governance forms. Furthermore, we believe that the consideration of particular projects as a unit of analysis might offer more specific results about each kind of network. In this sense it would be of interest to analyse governance structures in which partners are featured differently (firm-firm, customer-supplier, and so on) comparing administrative and social factors with those applied in sponsored networks. Finally, with the aim of generalizing the results obtained, we also find it of interest to contrast our findings with other

samples of technological international networks because of the increasing relevance of this kind of cooperation for the development of countries and with the aim of capturing the richness of network governance choices.

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