WHAT VARIABLES AFFECT, AND HOW, GOVERNANCE NETWORKS. APPROACH FROM TRANSACTION COSTS THEORY

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Abstract

This paper provides an analysis of governance structures in networks. The transaction costs theory provides a description of which variables affect governance forms but it does not explain how they affect and what variables have a great influence. Two questions analyses this theory: Firstly, transaction costs theory tries to explain variability of governance forms through the study of causal relations between the variables that affect the governance of networks. Thus the greater the specificity, uncertainty and frequency in a network, the more hierarchized the form of governance. Similarly, the greater the possibility of measuring technological performance in technological networks is, the lesser the opportunistic behaviour and, therefore, the safeguard mechanisms. Secondly, transaction costs theory considers that the most efficient form of governance structure is that which minimizes not only transaction costs but also opportunistic behaviour. This criterion is certainly restrictive; thus the management literature remarks that the unsuccessfulness of networks is due, among other reasons, to the poor functioning of networks whose objectives would be to solve conflicts, coordinate tasks and distribute results.

Taking this departure point, our study propose a model to analyse the governance structure of a network that allows to study the variability of governance forms and their efficiency, and also that provides an answer to three questions: How is the governance form in networks structured? What factors influence the variability of networks governance forms? What is the most efficient or suitable governance form of networks?

In this work, we used data collected from a large sample of technological networks developed under the V Framework Programs (1998-2002) retrieved from the publicly available CORDIS (Community Research Development Information Service) projects database.

Keywords

Technological networks, governance, transaction cost.

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1 Introduction

Theorists and practitioners of management have recognized technological networks as a strategic reality. From the firm scope, an important increase of the joint projects in the processes of technological development has taken place because of technological networks constituting a source of innovation as opposed to the classic and risky internalisation of this type of activities. The purpose of this paper is to provide theoretical and empirical evidence on efficiency governance form in technological networks through an exploratory analysis.

We will consider that the performance of a joint project, as is shown in the literature, supposes on the one hand the development of a technological process (technological process) and, on the other hand the existence of a governance structure (technological network) to develop it. In the development of the technological process a set of partners (firms, universities, research centres, and so on) are involved and, through a series of stages (identification of needs, technological description, and so on), carry out technological activities (basic or applied research, prototype, and so on) in order to achieve diverse objectives (patents, new products, training, etc.). To develop the technological network it is necessary to establish a governance structure whose objective is to manage the activities and relations among the partners in order to fulfil the goals of the technological network (Powell et al. 1996; Gulati et al. 2000; Hagedoorn et al. 2000).

From this departure point, our study focuses on three questions: How is the governance form in technological networks structured? What factors influence the variability of technological networks governance forms? What is the most efficient or suitable governance form of technological networks? By examining the example of networks arising from European Union R&D Framework Programmes, we seek to answer these key questions by approaching the analysis through transaction costs theory.

In the next section, we present a concise overview of relevant literature relating to governance structures and the issue at hand. We subsequently explain our research method and the model of governance structures and discuss our findings in section four. In the last section of the paper, we provide conclusions and some suggestions for future empirical research.

2 Conceptual Framework

Regarding the first question of how the governance form in technological networks is structured, Gulati (1998) defines governance structures as the formal contractual structures used to organize partnerships in strategic alliances. Williamson (2002) points out that the objective of governance structures is to infuse order in a relationship where potential conflict can arise, and where opportunities for common gain exist. Williamson (2202) also illustrates that the mode of governance depends on the incentive intensity, the administrative controls and the legal regime.

Technological networks as voluntary arrangements between two or more firms, as Gulati (1998) points out, require a suitable governance structure whose objectives are to solve conflicts (Mohr and Spekman, 1994), coordinate common tasks (Geringer, 1991) and distribute results (Ring and Van de Ven, 1994).

Furthermore, the governance structures in R&D networks are influenced by the dilemma between conflict and cooperation (Gulati, 1998; Williamson, 2002) which arises in networks because they are made up of firms and organizations that have their own objectives which do not always coincide with those of the network. This circumstance can generate discrepancies among. Marschak (1974) has described this situation based on the concordance of objectives using three levels: team, foundation and coalition, i.e., ranging from unanimity among partners to discrepancy. This feature of networks requires the inclusion of certain mechanisms, the safeguard mechanisms, in governance structures whose objective is to avoid opportunistic behaviours.

Regarding the second question of the factors that influence the variability of technological networks governance forms, the literature shows a great variety of them (Powell, 1990), and from transaction costs theory this issue has a twofold approach. The first one analyses how governance structure varies, determining its limits. Williamson (2002) considers the network as a contractual form between the market and the firm; in a heuristic way, he states that the choice of 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 governance structure of networks varies from those that are 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 the interaction and concordance of objectives are greater.

The second one analyses what factors affect the variability of governance forms. Transaction costs theory explains the configurations of governance structures emphasizing the degree of hierarchical and safeguard mechanisms they embody, pointing out the set of variables they include (Robertson and Gatignon, 1998; Willianson, 2002). Regarding hierarchical mechanisms, the first variable is the external uncertainty, referring to both demand (which concerns the fluctuation and unpredictability of demand) as well as technology (which refers to the probability of emergence of technological improvements). Another one is the specificity of assets, because the transaction of technological assets involves investments in human and physical capital that cannot be redeployed without losing productive value. The last one is the frequency, which refers to the periodicity with which technological transactions occur. Safeguard mechanisms in the governance structure arise with the need to minimise opportunistic behaviours. It is argued that opportunistic behaviour arises from behavioural uncertainty which concerns the difficulty of observing and measuring the adherence of the transacting parties to the contractual arrangements and the difficulty of measuring the performance of these parties. In this case, the variables indicated in the literature that influence the governance structure are the ability to measure the technological performance and the firm's prior experience with networks.

Once the factors that influence the governance forms have been identified, we will analyse the variability of governance forms. Transaction costs theory tries to explain this variability through the study of causal relations between the variables that affect the governance of technological networks (Brockhoff, 1992; Gulati, 1998; Artz and Brush, 2000; Willianson, 2002). Thus it is proposed, from a classic management framework, that a positive and significative relationship exists among uncertainty, specificity and frequency with the hierarchy mechanisms in the network. Thus the greater the specificity, uncertainty and frequency in a technological network, the more hierarchized the form of governance. Similarly, the greater the possibility of measuring technological performance in technological networks is, the lesser the opportunistic behaviour and, therefore, the safeguard mechanisms.

This approach, though, does not offer explanation about what variables have a great effect on governance forms from a quantitative point of view, that is, how each variable affects governance forms or what relationship exists between these variables. Such issues have been reflected in the research which has questioned the validity of the model. Transaction costs theory does not offer as good an explanation as do the results of empirical studies (Zajac and Olsen, 1993), the reason for which may be that governance structures in technological networks have their own singularities.

In conclusion, a certain controversy is observed between transaction costs theory and the empirical evidence that shows the causal relationships which influence the variability of governance forms of technological networks.

Finally, the third question we will analyse is that of determining the most efficient form for governing technological networks. In this sense, Walker and Weber (1984) show a previous model in which they consider that the most efficient form of network governance is that which minimizes transaction costs. These authors exclusively consider specificity as explanation variable and the relationship between specificity and management costs. In their study, Walker and Weber implicitly suppose the correct performance of the network and they consider that efficiency is achieved when governance costs are minimized.

In general, transaction costs theory considers that the most efficient form of governance structure is that which minimizes not only transaction costs but also opportunistic behaviour (Willianson, 2002). This criterion is certainly restrictive; thus the management literature remarks that the unsuccessfulness of networks is due, among other reasons, to the poor functioning of networks whose objectives are to solve conflicts, coordinate tasks and distribute results.

Taking into account the above relationships we will construct a model that, in our opinion, collects the variables that determine the governance structure of a technological network.

3 Methodology

3.1 The model of governance structure

In this section we will propose a model to analyse the governance structure of an technological network that will allow us to study the variability of governance forms and their efficiency.

The governance structure of an technological network can be analysed as a model in which the governance structure will be the variable (*G*), governance of the technological network. In accordance with Gulati (1998) we can define the governance variable (*G*) as the formal contractual structure used to organize partnerships in networks. The main objectives of governance structure are to solve conflicts, coordinate common tasks, distribute results and avoid opportunistic behaviour.

Similarly, we can define the hierarchy variable (*H*) and safeguard variable (*S*). This way, the hierarchy variable represents the range of use of hierarchical mechanisms in the technological network while the safeguard variable (*S*) represents the range of use of safeguard mechanisms in the governance structure of the technological network.

In these definitions we assume that the limits of variability of the two variables, H and S, are the market and the firm. Therefore the following question is: What does this variability depend on? As we have shown in the literature review, the hierarchy and safeguard variables depend on endogenous and exogenous variables to the network.

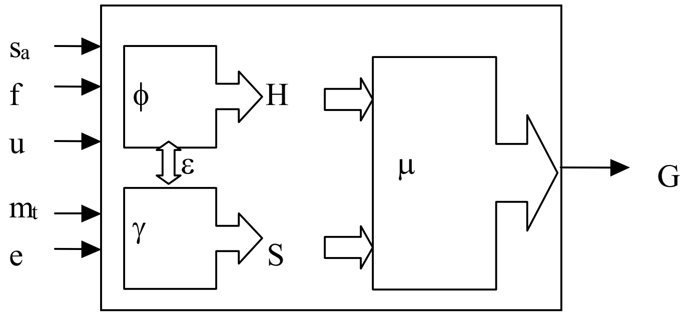
In the case of the hierarchy variable it depends on the technological specificity of assets to be developed in the network, on the frequency of contacts among partners that take part and on the uncertainty of environment. Therefore, $H = \phi (sa, f, u)$; where: s_a = specificity of asset variable, f = frequency variable, u = uncertainty variable.

As for the safeguard variable, it depends on the measure of technological results and on the prior experience of partners in networks. Hence: $S = \gamma (m_t , e)$, where: m_t = measure of technology variable, e = prior experience variable.

As we have mentioned, the governance structure of a network is comprised of a hierarchical structure and certain safeguard mechanisms which can vary from frameworks near to the market up to structures near to the firm. Thus we can formulate that the governance variable of an technological network depends on both the hierarchy variable as well as on the safeguard variable, that is $G = \mu (H, S)$.

This represents a system of three equations, such that, $G = \mu (H, S)$, $H = \phi (s_a, f, u)$ and $S = \gamma (m_t , e)$, in which we will study the interrelations between the input and output variables, that is, we will determine the μ, ϕ, γ functions.

Figure 1: The model of governance



3.2 Sample

Before describing the data and presenting the empirical analysis we will explain a series of initial conditions about the study. Firstly, we have used the network as unit of analysis. Secondly, the measure of the efficiency in governance form of technological network is analysed as partner's behaviour, rather than measured by a count of technological results as in databases on alliances. There exists a double reason for this. On the one hand, the subjectivity of the measure, i.e. the efficiency in governance subsystem is defined as the optimization degree in the functions of coordination, to solve conflicts, to distribute results and to avoid opportunistic behaviours among partners. On the other hand, there is not much empirical research on this issues that make difficult to treat the efficiency in governance form of technological network as we expect. Therefore, due to the global character of our analysis and the lack of suitable databases and references we have decided to make a survey designed following a mixed methodology, through the use of experts (Delphi method) and the search for a representative sample.

To overcome the difficulty of measuring subjective variables, we have based the items on previous research, using a Likert scale to weight these variables (Robertson and Gatignon, 1998).

The empirical work is based on an extensive survey of technological networks developed under the V European Research and Development Framework Programme between the years 1998 and 2002. The data were collected in 2002 through a sample of institutions which frequently take part in European technological networks. At that time, 350 institutions were identified in the CORDIS database (Community Research and Development Information Service). We elaborated a complete questionnaire that we pre-tested with a small group of institutions from different countries before sending out the final version. The survey yielded 275 usable responses, which represent a response rate of 78.5 per cent. The respondents were predominantly managing directors and CEOs of these institutions.

3.3 Measure of variables

The measure of variables implies two initial problems. Firstly in the specific literature*, G, H* and *S* have been considered as latent variables, which do not allow us to measure them directly. For that reason, we will take the works of Robertson and Gatignon (1998) and Williamson (2002) as a starting point and we consider that G, H and S are constructs of other variables widely referenced in the literature. Secondly, from a management point of view, the problem lies in how to measure interrelation variables, organizational variables and variables related with the partner's behaviour. In this type of study variables of this kind are usually measured using Likert scales. In our study most of the variables are measured by single items in the questionnaire. We have mainly used a 5 point Likert scale to enable the respondent to indicate his/hers degree of agreement with the statement in the questionnaire on a scale from 1 –strongly disagreeing with the statement, to 5 –strongly agreeing with the statement. Furthermore in the analysis we have discriminated between two kinds of projects, applied projects (or exploitation projects) and less applied projects (or exploration projects), as Dyer and Nobeoka (2000 determine.

March (1991) claims that 'the essence of exploitation is the refinement and extension of existing competencies, technologies and paradigms. The essence of exploration is experimentation with new, uncertain alternatives'. While exploitation involves using existing information to improve efficiency and returns from present strategies, competencies, and procedures, exploration entails searching and experimenting to find emerging innovations that will produce future profits.

The hierarchical subsystem

As for the output hierarchy variables, the measures are based on the similarity of the network's structural elements with the market or with the firm (Gulati and Shing, 1998; Hagedoorn et al. 2000). The mechanisms used are derived from the need to plan, decide and organize the technological activities to be developed. With respect to the network planning, diverse criteria are cited in the literature. The first one is linked to partners' equilibrium, and in European transnational projects this also includes the country factor, which seeks certain equilibrium in the distribution of tasks. The second criterion 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 the network and the consensus between partners (Hagedoorn et al. 2000). As for the organisation of activities among partners, it is worth mentioning that two situations are the most common: teams within the network and the independent development of tasks.

The reliability of measures and descriptive statistics has been analysed and the results are reflected in Appendix I. To asses reliability we computed Cronbach alphas for each multiple scale item. We have also homogenized and simplified the variables with the aim of obtaining constructs or factors that represent each set of variables.

To measure the input variables of this subsystem, as is pointed out in transaction costs theory, we will base these measures on specificity, uncertainty and frequency. The first one, specificity of assets, is the core determinant in transaction costs literature (Robertson and Gatignon, 1998; Williamson, 2002). The transfer of specific assets involves investments in human and physical capital that cannot be redeployed without losing productive value (e.g. a plant and equipment suited to produce a specific product or to serve a particular customer, brand name, investments in capital, specific knowledge and expertise, and so on). In technological networks, partners sign a contract requiring specific investments which lead to a relationship of mutual dependence. In our research the measure of the specificity is based on a five item scale which assesses finance, plant equipment and marketing commitments, and the extent to which the technology represents a core competence and a high degree of collective learning. External uncertainty includes both demand uncertainty and technological uncertainty. Demand uncertainty concerns the fluctuation and unpredictability of demand, that is, it assesses volatility of demand. Technological uncertainty refers to the probability of improvements in technology rendering the current technology development effort obsolete. We do not take the frequency variable into consideration because the networks of our sample are sponsored by European Framework Programs and the temporal variable is defined a priori. The reliability of measures and descriptive statistics are reflected in the Appendix I.

The safeguard subsystem

The safeguard output variable is related to the mechanisms which govern R&D networks in order to avoid opportunistic behaviour (Williamson, 2002). The specific literature on networks asserts that in the selection of a partner, previous experiences and trust serve as important factors in minimizing 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 supervision mechanisms (reports and meetings among partners, the role of coordinator and so on) are frequently used as safeguard mechanisms (Ring and Van de Ven, 1994). Appendix II collects the reliability of measures and descriptive statistics for this variable.

To measure the input variable of safeguard subsystem we will use behavioural uncertainty (or internal uncertainty) and the firm’s experience in technological networks (Robertson and Gatignon, 1998). Behavioural uncertainty is related to the ability to measure innovation performance concerning the specificity with which the performance of the innovation was established and monitored. The firm’s experience with technological networks refers to the number of technology development projects in which the firm has been involved over the past five years, and also evaluates past technological network success using different criteria, such as the achievement of objectives or the level of market penetration obtained. Safeguard variables were measured in these terms by single items. Reliability of measures and descriptive statistics are reflected in the Appendix II.

Governance subsystem

Finally, regarding the measure of the network governance variable, we have already mentioned that objectives of governance structures are to solve conflicts among partners, coordinate tasks and distribute results, and finally to avoid opportunistic behaviour (Willianson, 2002). The efficiency of governance structure is measured in these terms by simple items. Reliability of measures and descriptive statistics are reflected in the Appendix III.

We obtain satisfactory results for validity the variables, as indicated the Cronbach alpha values (> 0.6).

4 Analysis of results and discussion

We have already determined the functions of governance (μ), hierarchy (ϕ) functions and safeguard (γ) in each subsystem. We will proceed now to analyse whether there is any interrelation between the hierarchy subsystem and the safeguard subsystem as we propound in our model. Afterwards, we will determine which model –linear or non linear– offers a better adjustment to the whole model of governance.

As for the interrelation between the hierarchy subsystem and the safeguard subsystem we will determine the significance level of interrelation variables, ε_1 and ε_2, which represent the incidence of input variables from one subsystem in the other (Hirschhorn et al. 2001). We have performed a pre-test through a linear regression which shows the independence between subsystems in each of the projects considered.

The regression model shows (as seen in the table 1) the low interrelation degree between the group of input variables and the corresponding subsystems for what we can consider , ε_1 and ε_2 residual variables and therefore the independence between hierarchy and safeguard subsystems.

Regarding the linear or non lineal nature of governance model functions, in the case of hierarchy (ϕ) and safeguard (γ) functions, from the result of the pre-test (Table 1) we can see the difficulty in adjusting these functions to a linear model ($\mathbb{R}^2$: 0.35; 0.27; 0.38; 0.33 in the case of exploitation projects; $\mathbb{R}^2$: 0.14; 0.18; 0.32; 0.25 in the case of exploration projects) hence, we can assume their non linear nature. As for the governance function (m), table 2 shows the results of linear regression which reveals the impact of hierarchy and safeguard functions on governance function.

Table 1: Linear regression model ($H=\phi\ (s_a ,f\ u); S= \gamma\ (m_t, e)$)

Variable	EXPLOTATION				EXPLORATION			
	Hierarchy variable		Safeguard variable		Hierarchy variable		Safeguard variable	
	Mod. 1	Mod. 2	Mod. 1	Mod. 2	Mod. 1	Mod.2	Mod. 1	Mod. 2
Constant	-0.032	-0.051	0.011	0.009	0.003	0.010	-0.123	-0.101
Product category-specific assets	**0.373**	**0.322**	0.117	-	**0.127**	**0.115**	0.034	-
External uncertainty								
Demand volatility	0.087	0.054	0.037	-	0.027	0.027	0.025	-
Technological uncertainty	**-0.225**	**-0.191**	0.084	-	**-0.168**	**-0.143**	0.011	-
Behavioural uncertainty								
Ability to measure innovation performance	-0.112	-	**-0.371**	**-0.350**	-0.081	-	**-0.210**	**-0.197**
Firm's experience	0.037	-	**-0.525**	**-0.583**	-0.002	-	**-0.281**	**-0.254**
$\mathbb{R}^2$	0.35	0.27	0.38	0.33	0.14	0.18	0.32	0.25

Table 2: Linear regression model (governance function, $G= \mu\ (H, S)$)

Variable	Exploitation	Exploration
Constant	0.036	-0.125
Hierarchy degree	**0.179**	**0.107**
Safeguard degree	**0.451**	**0.235**
$\mathbb{R}^2$	0.27	0.33

It is also observed in this case that the results are not adjusted to a linear model ($\mathbb{R}^2$: 0.33 in the case of exploitation projects; 0.27 in the case exploration of projects), hence we will try to approach the system through non linear analysis.

In order to test the model of governance with a non linear model we will perform an artificial neural network (ANN) with Multi-Layer Perceptron (MLP), which allows the prediction of non linear relationships in causal studies and is considered one of the most reliable methods for predictive analyses (see for example, Smith and Gupta, 2000).

In the training phase we obtained the best adjustment of neural networks, determining the number of hidden nodes as well as the transfer function for the three possible combinations of relationships among variables.

Table 3 details the parameters of ANN analysis. For this analysis, we used a restriction in which RMS error is lower than 0.001 for training and validation stages, and the response percentage higher than 95%. We selected the automatic generation of the hidden layer.

Table 3: Parameters of ANN analysis

		Hidden layers		**Activation Function (Hidden Layer)**	**Activation Function (Output layer)**	**% Co-rrect**	**RMS error**
		Nº	***Modes***				
Exploitation projets	μ	1	2	Sigmoid	Linear	87	0.04124
	ϕ	1	3	Sigmoid	Linear	91	0.04076
	γ	1	2	Sigmoid	Linear	85	0.05120
Exploration projects	μ	1	2	Sigmoid	Linear	75	0.06395
	ϕ	1	3	Sigmoid	Linear	82	0.05218
	γ	1	2	Sigmoid	Linear	79	0.06072

To study governance (μ), hierarchy (ϕ) and safeguard (γ) functions we will graphically represent such functions to show the form and to observe whether concavity exists, in which case it will correspond to an efficiency point. The software used allows the three-dimensional (3D) representation, showing the function related to two variables, maintaining the other variables constant (ceteris paribus). In the graphic we represent the two kinds of variables that show the biggest impact for both types of projects studied (Figures 2a and 2b; 3a and 3b; 4a and 4b).

Starting from these results we can respond to several questions. How is the governance form in technological networks structured? What factors do they influence and how, in the variability of the governance forms of technological networks? Is it possible to make reference to efficiency when governance forms of technological networks are analyzed?

Regarding the first question about how the governance form in technological networks is structured, from the transaction costs theory approach we have seen that governance forms make reference, on one hand, to the hierarchical structure whose objectives were task coordination, planning and control, and on the other hand, to the existence of certain safeguard structures whose objective was to avoid opportunistic behaviour in the management of technological networks. This way, the hierarchical structure of technological networks, is sustained in the planning, in which the principle of equal distribution of tasks among partners and countries has greater weight than the technological specificity of the partner itself. Also it is observed that in decision making the opinions of partners are considered as much as that of the network coordinator. These features corroborate two characteristics of technological networks: first, the small amount of hierarchical structuring, since the performance of networks is based on consensus; and second, the search for equity in the distribution of tasks between the partners (Robertson and Gatignon, 1998; O´Sullivan, 2003). With respect to safeguard mechanisms to avoid conflict situations, they are supported by suitable planning both in terms of responsibilities and contributions of partners and in terms of a results distribution policy. Another important aspect indicated in the literature of network management is the selection of partners, a crucial aspect which contributes to the construction of a suitable collaboration environment among partners, both in terms of communication as well as in understanding (Geringer, 1991; Mohr and Spekman, 1994; Saxton, 1997; Gulati and Singh, 1998). To create these conditions it is observed that technological networks are formed among partners who have collaborated in previous experiences. It contributes to a good climate because the partners already have experience working in networks and, furthermore, the familiarity between partners facilitates the creation of dynamics of commitment and confidence.

Figure 2a, 2b: Three-dimensional (3D) representation of function (ϕ)

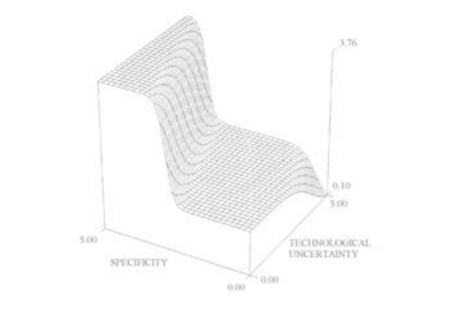
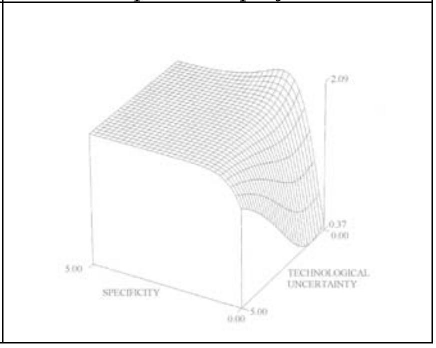
Exploitation projects	*Exploration projects*
	

Figure 3a, 3b: Three-dimensional (3D) representation of function (γ)

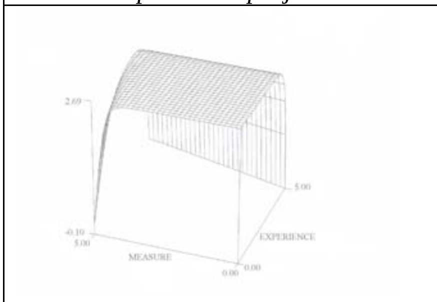
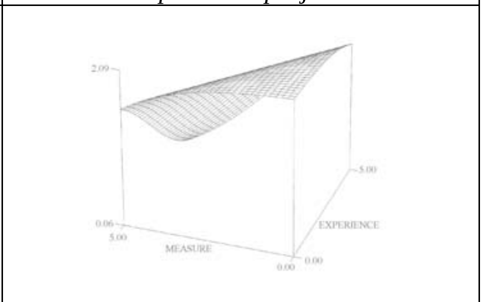
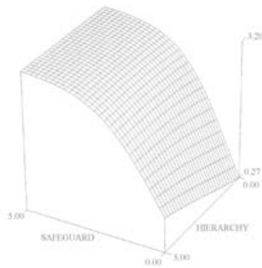
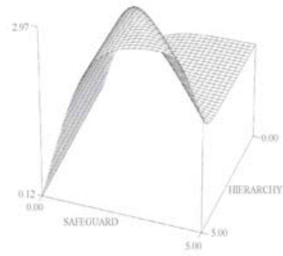
Exploitation projects	*Exploration projects*
	

Figure 4a, 4b: Three-dimensional (3D) representation of function (μ)

Exploitation projects	*Exploration projects*
	

Regarding the second question, that is, what factors influence the variability of the governance forms of technological networks again we have taken the departure point of transaction costs theory. Traditionally, specificity and external uncertainty have been taken into account when studying the variability of hierarchical structures as well as the measure of technology and experience with alliances in the study of safeguard mechanisms of technological networks (Brockhoff, 1992; Robertson and Gatignon, 1998). Our results confirm the soundness of these constructs both in reliability and validity.

With respect to how these variables affect the governance structure of technological networks, transaction costs theory does not explain in what way they condition governance structures (Zajac and Olsen, 1993). Hence to determine how these variables affect governance function we have applied the systems theory which allows us to study the effect of each input variable on output variables (Hirschhon, et al., 2001). We have delimited two subsystems: the hierarchical subsystem and control subsystem.

The hierarchical subsystem explains the relationship between the hierarchy variable –the output variable– and specificity and uncertainty –the input variables. The first conclusion shown by the analysis is the non linear nature of this relation and the different influence of each variable on hierarchical function. As shown in figures 2a and 2b the specificity variable has greater influence than technological uncertainty on the hierarchical degree presented by the technological network. To delve into this analysis we have used a dual approach, observing on the one hand, the impact of each variable on governance form and, on the other, through a 3D representation, examining its influence on the hierarchy function and the safeguard function. We have taken the impact of each variable from the regression analysis (table 1), in spite of the low adjust level of these coefficients, because they may offer a range of magnitude.

Our results on the hierarchy function show that the variables which have more impact on the variability of this factor are specificity (0.373 in the case of exploitation projects and 0.127 in the case of exploration projects) and to a lesser degree -with negative sign- technological uncertainty (-0.225 in the case of exploitation projects and -0.168 in exploration projects), with demand volatility not being significant (0.087 in the case of exploitation projects and 0.027 in the case of exploration projects). Our result confirm previous research (Robertson and Gatignon, 1998; Williamson, 2002) in which specificity is marked as the most significant variable in the network structure. For its part, technological uncertainty has negative incidence in the hierarchical structure of network. Dosi (1988) points out that the less applied is a technology, the greater the levels of uncertainty are, both in terms of expected results as in time to obtain them. Our results confirm this circumstance both in invention and innovation projects. We may indicate that incidence of hierarchical structure is higher in innovation projects. Also in the same sense Dyer and Nobeoka (2000) show two distinct kinds of networks depending on technological objectives of the network. The first are networks that serve to explore information with a large number of partners characterized by a low structuring with the objective of obtaining technological information; and second, networks which exploit information in order, for example, to obtain an innovative product which constitutes a highly structured network with a small number of partners. Therefore, we can affirm that whenever the specificity of a technology is greater -and lesser, therefore, the uncertainty- there will be a greater hierarchy structure in the network.

The 3D analysis shows and confirms the different influence of technological uncertainty and specificity on hierarchy degree, both in the case of invention projects and innovation projects (fig. 2a and 2b).

It is worth mentioning, in the case of more applied projects, that uncertainty displays an almost constant value whereas specificity shows two clearly differentiated levels. The first level corresponds to a smaller degree of hierarchy that, as we indicated above, will be related to low levels of specificity in projects which correspond, for example, to diffusion projects. On the other hand, the second level will correspond to a more hierarchized structure which corresponds, for example, to projects with high levels of specificity as in the case of innovation projects to obtain new products.

Regarding the safeguard function we can see that variables which have more impact on the variability of this factor -with negative sign- are experience (-0.525 in the case of exploitation projects; -0.210 in the case of exploration projects) and the ability to measure innovations (-0.371 in the case of exploitation projects; -0.281 in the case of exploration projects). This first approach shows a similar impact of two variables on safeguard mechanisms. The 3D representation (fig. 3a and 3b) shows that the behaviour of these two variables is very similar: for small values of the variable it increases very quickly, reaching a value that practically stays constant for the other values of variables. Therefore, we could affirm that the safeguard degree is constant in both types of projects and independent of the variability of technology measure and experience.

Regarding the last question, as to whether it is possible to make reference to efficiency in governance forms of technological networks, firstly it is necessary to remark on what an efficient form of governance is. We consider that a governance structure is efficient when its objectives are to solve conflicts (0.704), to coordinate tasks (0.655), to allocate results (0.614) and to avoid opportunistic behaviour (0.711). Our results show that governance structure has these three actions (Willianson, 2002). On the other hand we have found a causal non linear relationship between the hierarchy degree and safeguard degree in the governance form observing that it varies according to the kind of project. Thus, in exploration projects these two variables influence the governance form to a lesser extent (hierarchy, 0.107; safeguard, 0.235) than in exploitation projects (hierarchy, 0.179; safeguard, 0.451). These results corroborate those of previous empirical works, already classics in transaction costs theory, which conclude that the greater the applicability of projects, the greater the governance structure needed to manage the technological network (see, for example, Willianson, 2002). Also we will emphasize that the hierarchy degree has a smaller incidence than the safeguard degree on efficiency. This outcome reinforces the above results regarding the low hierarchy degree of technological networks, where control is the main characteristic of their management (Baker, 1990; Ring and Van de Ven, 1994; Robertson and Gatignon, 1998). Specifically, safeguard degree has an incidence of contingent nature on efficiency which can be seen in the graphic representation (fig. 4a and 4b). In the case of exploration projects the efficiency point is reached with low levels of safeguard above which a substantial increase in network inefficiency is observed. On the other hand, in exploitation projects we see that a greater safeguard degree is necessary, as previously pointed out, and from a certain level onward significant increases of efficiency do not occur.

Therefore we may conclude on the one hand, the different impact of variables (on governance function) and their non linear incidence, and on the other hand to confirm the contingent nature of the impact of two functions, H and S on governance function.

5 Conclusions

In this paper we have tried to explain governance forms of technological networks trough transaction costs theory. Two questions analyse this theory. Firstly, transaction costs theory tries to explain variability of governance forms through the study of causal relations between the variables that affect the governance of technological networks. Thus it is proposed, from a classic management framework, that a positive and significative relationship exists among uncertainty, specificity and frequency with the hierarchy mechanisms in the network. Thus the greater the specificity, uncertainty and frequency in a technological network, the more hierarchized the form of governance. Similarly, the greater the possibility of measuring technological performance in technological networks is, the lesser the opportunistic behaviour and, therefore, the safeguard mechanisms. This approach, though, does not offer explanation about what variables have a great effect on governance forms from a quantitative point of view that is, how each variable affects governance forms or what relationship exists between these variables. Furthermore, a certain controversy exists between transaction costs theory and the empirical evidence that shows the causal relationships which influence the variability of governance forms of technological networks. Secondly, transaction costs theory considers that the most efficient form of governance structure is that which minimizes not only transaction costs but also opportunistic behaviour. This criterion is certainly restrictive; thus the management literature remarks that the unsuccessfulness of networks is due, among other reasons, to the poor functioning of networks whose objectives are to solve conflicts, coordinate tasks and distribute results.

Taking this departure point, our study propose a model to analyse the governance structure of an technological network that allows to study the variability of governance forms and their efficiency, and also that provides an answer to three questions: How is the governance form in technological networks structured? What factors influence the variability of technological networks governance forms? What is the most efficient or suitable governance form of technological networks?

Our results represent a starting point for future research in order to widen theoretical and empirical evidence about the governance of technological networks. As a research agenda, we suggest 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 an influence on governance forms. Furthermore, we believe that the consideration of particular projects as a unit of analysis might offer results more specific 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 hierarchy and safeguard mechanisms with those applied in sponsored networks. Finally, to generalize the results requires 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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Appendix I: Hierarchy subsystem: descriptive statistics of input variables

Variable	Description Value	Factor Analysis	Reliability Analysis	Description Value	Factor Analysis	Reliability Analysis
	Average	Weight	Cronbach alpha	Average	Weight	Cronbach alpha
	EXPLOITATION			EXPLORATION		
			Hierarchy Subsystem			
Hierarchy variable (Output)			0.813			0.708
Planning						
Technological and scientific knowledge	2.5	0.756		1.7	0.542	
Equal distribution among all partners and countries	3.6	0.837		1.5	0.499	
Ad hoc decisions	2.1	0.644		1.8	0.512	
Requirement of UE	3.0	0.785		2.1	0.634	
Decision making						
The opinion of coordinator	3.7	0.811		3.0	0.745	
The opinion of partners	4.1	0.823		2.5	0.710	
Organization						
Each partner develops activities independently	3.4	0.530		1.6	0.459	
Teams develop activities	2.5	0.372		1.4	0.391	
Hierarchy variable (Input)						
Specificity			0.712			0.675
Collective learning	3.3	0.793		2.4	0.597	
Plant and equipment	3.1	0.749		2.5	0.551	
Commitments in finance	2.0	0.684		2.0	0.460	
Core competence	2.7	0.751		1.7	0.397	
Marketing commitments	1.9	0.637		1.5	0.413	
Demand volatility (External uncertainty)			0.623			0.601
Demand is difficult to forecast	2.7	0.634		2.2	0.581	
Markets are uncertain	2.9	0.598		2.7	0.603	
Technological uncertainty (External uncertainty)			0.804			0.764
The technology is stable	2.5	0.811		2.5	0.538	
Life cycles are short	3.1	0.793		2.4	0.611	
The technology is moving very fast	3.5	0.841		2.8	0.604	
Technology has reached a plateau	2.8	0.632		1.9	0.561	
Technological pressure is intense	3.6	0.603		2.3	0.637	
The technology moves rapidly	3.9	0.698		3.1	0.598	

Appendix II: Safeguard subsystem: descriptive statistics of input variables

Variable	Description Value	Factor Analysis	Reliability Analysis	Description Value	Factor Analysis	Reliability Analysis
	Average	**Weight**	**Cronbach alpha**	**Average**	**Weight**	**Cronbach alpha**
	EXPLOITATION			**EXPLORATION**		
			Safeguard System			
Safeguard variable (Output)			0.732			0.647
Selection						
Previous experience	4.0	0.794		3.2	0.698	
Scientific and technological qualification	3.3	0.422		3.0	0.711	
Requirements of EU programmes	3.7	0.617		3.5	0.644	
Responsibilities						
Contribution of each partner	3.9	0.811		3.1	0.670	
Allocate profits	3.8	0.819		3.2	0.756	
Define tasks	3.3	0.790		2.5	0.634	
Monitoring						
Partner reports	2.7	0.450		2.4	0.618	
Informal communications	3.3	0.547		2.0	0.599	
Meetings with partners	4.1	0.765		3.6	0.647	
The project coordinator	3.2	0.201		2.4	0.503	
Safeguard variable (Input)						
Ability to measure innovation performance			0.617			0.604
Goals for innovation clearly defined in advance	4.1	0.624		3.2	0.637	
Quality of innovation is known	3.7	0.511		3.1	0.584	
Specified measures to evaluate the success of innovation	3.2	0.684		2.7	0.640	
Firm's experience with alliances						
Number of alliances already established by the firm	2.4	0.540		2.1	0.517	
Our program of alliances has been a success	2.3	0.624		3.2	0.609	
Most our alliances have met our objectives	2.3	0.537		2.7	0.576	
Our alliance efforts have been more successful than competitors	2.3	0.502		1.4	0.278	
Innovations by alliances have achieved good market penetration	1.8	0.321		2.0	0.424	

Appendix III: Governance subsystem: descriptive statistics of input variables

Variable	Description Value	Factor Analysis	Reliability Analysis	Description Value	Factor Analysis	Reliability Analysis
	Average	**Weight**	**Cronbach alpha**	**Average**	**Weight**	**Cronbach alpha**
	EXPLOITATION			**EXPLORATION**		
	Governance Subsystem					
R&D governance variables			0.697			0.621
To solve conflicts	3.1	0.704		2.9	0.683	
To coordinate task	2.9	0.755		2.5	0.641	
To distribute results	2.5	0.614		2.0	0.570	
To avoid opportunistic behaviour	2.5	0.711		1.8	0.421	