INTER-ORGANIZATIONAL ARCHITECTURE AND INNOVATIVE PROCESSES

by

MAURIZIO SOBRERO

Laurea, Economia e Commercio
Università degli studi di Bologna
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Signature of Author ____________________
MIT Sloan School of Management
9/24/96

Certified by ____________________
Edward B. Roberts
David Sarnoff Professor of Management of Technology
Thesis Supervisor

Accepted by ____________________
Birger Wernerfelt
Chariman, Ph.D. Program Committee

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ABSTRACT

The research presented in this thesis focuses on inter-organizational relationships in the development of innovation addressing two questions: what kind of impact do such relationships have on the partners involved and which processes account for these effects.

Using a multidisciplinary approach, I develop a theoretical framework with two fundamental dimensions characterizing the structuring of inter-firm relations: contractual coordination and procedural coordination. Contractual coordination refers to the mutual exchange of rights among the parties involved. Procedural coordination refers to the mutual exchange of information among the parties. Through a quantitative meta-analysis of 32 empirical studies I show that both dimensions are influenced by the characteristics of the tasks performed in the relationship; that they fulfil different but complementary roles in its governance; and that their systemic fit impacts its performance.

I test these findings with an empirical study on 50 manufacturer-supplier relationships in new product development in the European major home appliance industry, showing a clear trade-off between short term efficiency-increasing relationships and long term learning-enhancing ones. Efficiency-increasing relationships require fewer coordination efforts and are initiated later during the project; communication is less frequent and occurs through non dedicated channels; and problem solving is generally sequential rather than overlapping. Learning-enhancing relationships require partner contacts well ahead of the project tasks, working in overlap with higher levels of communication, frequently through dedicated channels.

In the second part of the thesis I articulate these results using social network analysis

concepts and techniques. Choices over the amount of relational activity, the variance in the relational set, and the variance in the contexts of interaction are theoretically related to the characteristics of the tasks jointly performed by the actors and empirically verified using a complete relational set of 173 projects performed by 25 R&D units in the steel industry. Network autocorrelation models are then introduced to assess the hypothesized overall effect of relational strategies on individual actors' outcome.

This thesis contributes to the theoretical debate on inter-organizational relationship in three ways. First, it recomposes the institutional decisions driving the governance of inter-firm relations and their organizational implementation. Second, it shows the impact of alternative organizational arrangements on the relationship outcome in different contexts and using different methodologies. Third, it conceptualizes structuring alternatives using a relational perspective focusing on the single relation as the unit of analysis.

From a managerial perspective, the work aims to attract practitioners' attention to the need for a planned effort on the organizational implementation of inter-organizational relations which should simultaneously complement contractual negotiations, rather than sequentially supplement them. The empirical studies are modules stressing different operational aspects of this issue.

Thesis Committee: Edward B. Roberts (Chair)
David Sarnoff Professor of Management of Technology
Alfred P. Sloan School of Management, MIT
Stephan Schrader
Institute Professor of Management of Technology
Ludwig-Maximilians-Universität München
Marco Iansiti
Associate Professor of Technology and Operations Management
Graduate School of Business Administration, Harvard University

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> "Words mean rock and water, thus thoughts are hard and soft.
> But there are no words for what precedes words,
> no thoughts for what precedes thoughts.
> In the silence before words are spoken,
> and in the emptiness before thoughts are conceived,
> there is something which cannot be told, which cannot be thought.
> That's why words and thoughts are never enough"
> (*The Tao of Sailing*, Humanics, Atlanta, 1990)

Ed Roberts was my advisor when I first came to MIT as a Visiting Scholar in 1991 and ever since then has been a fundamental source of intellectual challenge and motivation. Despite these earlier encounters, which should have warned him against the dangers of interacting with an undisciplined Italian, he agreed to chair my committee. His complete support, assistance and continuos stimulus to go one step further what I could see forced me to improve my thoughts and ideas and complete my work.

Stephan Schrader tried to drop out of my committee by moving to Germany during my field work. He did not consider, though, that I would have been persistent enough to knock at his door in Munich, ask for hospitality and force him to steal his spare time from his lovely family to work with me. I then knew I was right in doing it, and even more so I do now, looking at how influential he has been and will be for they way I approach my research and profession.

Marco Iansiti always brought me back down to earth from my cloudy thoughts, whenever I could not hide behind the friendly alibi of English words and expressions. After long discussions we found to have not only a country and a language in common, but also research interests. Ever since, his enthusiasm and support for my work has significantly added to Ed's and Stephan's suggestions, always forcing me to consider multiple audiences and the practical meanings of what I was doing.

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My family always kept for me a secluded cove to shelter from the troubled waters of daily life. I owe them all I have achieved so far and what I will in the future. Finally, at the end of the long journey of formal education, I'd like to remember my uncle Giulio Giunti. He left us before I could begin to venture in the University world were he was so successful, but his wishes have always been in my heart during all these years.

This work is dedicated to my wife Donatella, for her love and support during these years of distant but close relationship, for the beginning of a new life of togetherness.

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CHAPTER 1
Introduction

The attention paid to inter-firm relations has been constantly increasing during the last years. Research has in turn emphasized the strategic appropriateness (Roberts, 1980; Roberts and Berry, 1985; Porter and Baden Fuller, 1987; Harrigan, 1988) the economic advantages (Williamson, 1979; Contractor and Lorange, 1988a: Kogut, 1988), and the learning implications of inter-organizational relations (Ciborra, 1991; Simonin and Helleloid, 1993). Scholars and managers are overwhelmed by terms such as "networks", "virtual corporation", "hollow corporation" and the like.

The central argument of this growing literature is that individual organizations can no longer rely on their own resources to compete in today's world. Rather, they should look for strategic interactions allowing them to effectively leverage internal resources by investing in some core competencies and contracting out other knowledge domains.

The analysis of innovation development processes is frequently pointed out as a prototypical example for the need to rethink organizational boundaries. The speed of technological progress, the increasing amount of resources needed to fully control the process and the shortening times for investment recovery are common phenomena in many industries. The rabbit in the hat to make this process work seems to be found in a distinctive capability in collecting and putting together several interdependent sources. Changes in the drug development process (Henderson, 1994), as well as in cars (Clark and Fujimoto, 1991; Nobeoka, 1993), mainframes (Iansiti, 1995; Iansiti and Khanna, 1995), and personal computers (Pine, 1993) are often used as examples.

Despite such growing enthusiasm, the issue of organizing productive activities within one single unit or spreading it across multiple units requiring some kind of coordination is not new. In the technological innovation literature one can trace it back to the early works of Schumpeter (1936) and of Usher (1955), where the engine of economic growth was in the entrepreneurial ability to combine different resources for the exploitation of original inventions.

Nevertheless, the debate is still ongoing as to whether or not it is worthwhile for an economic agent to pursue innovative activity independently. And if not, through which forms and under which legal protection mechanisms should the established relationship be managed. Much less attention, however, has been devoted to the detailed organizational structuring of the relations after they have been put into place. Managers and scholars are provided with empirically tested insights on whether or not to start an alliance or a joint venture (the if), but our understanding of the impact of organizational structure variables (the how) on the effectiveness of the relation is still poor.

The purpose of this dissertation is to focus on the "how" part of the problem. It is here argued that the structuring of inter-organizational relations directly and profoundly influences their outcome, and ultimately that of the actors participating in it. Using a multidisciplinary approach, I develop a theoretical framework linking the characteristics of the task jointly performed by the actors involved, the contractual arrangements chosen to govern the transaction, the coordination mechanisms selected for its implementation and the final outcome of the relationship. In the following chapters, I use different methodologies and research designs to articulate and empirically test this framework at the overall relationship level, at the actor level and at the ongoing process level.

This chapter is intended to provide the reader with a general understanding of the issues, the methodologies, the designs and the results of the studies performed. Section 1.1 discusses the theoretical premises and major conclusions of the studies on inter-firm relations focusing on relationships between task characteristics, inter-organizational structuring and performance. Section 1.2 presents the research framework of the dissertation and an overview of the empirical findings. Section 1.3 concludes, highlighting the theoretical contributions and the managerial implications of the dissertation.

1.1 Theoretical premises

1.1.1 Inter-firm relationships and innovative processes

The empirical observation of the increasing importance of interactions among legally distinguished units challenged the traditional image of an organization as an entity with well defined boundaries (Contractor and Lorange, 1988a). Clearly, one crucial activity influenced by these changes is the development of innovation. As a consequence, an increasing attention has been devoted to the role of inter-firm relations in the development of innovation (Roberts, 1980). Following Kogut (1988), we can identify three theoretical approaches for the analysis of inter-firm relations: a transaction-cost based approach, a strategic approach and an organizational learning approach.

Studies based on the assumptions and propositions of transaction cost theory

(Williamson, 1975; Williamson, 1985) focus on the characteristics of the interactions involved in the development of innovation (Ouchi and Bolton, 1988). Given actors' characteristics (propensity to opportunistic behavior and bounded rationality), task related factors (asset specificity and uncertainty) are used to identify the appropriateness to engage in interactions with other subjects and to determine the optimal governance structure (Pisano, 1990). Accordingly, research has been addressing the conditions under which the sum of production and transaction costs will be minimized through internalization (Pisano, 1991), market driven transactions such as licensing, or other intermediate forms of governance structure such as joint ventures (Hladik, 1988) and consortia (Watkins, 1991; Tripsas et al., 1995).

Complementary to the inward focus on efficiency achievements, the strategic perspective on organizational interactions stresses how, by pooling their resources and efforts towards innovation, all the partners involved would improve their competitive positioning (Contractor and Lorange, 1988b). Collaborative activities become a way to overcome asymmetries in the resource endowments and spread the risks associated with innovative activity (Combs, 1990), to control spillovers (Katz, 1986), or to limit the opportunities for new entrants in the market by indirectly rising barriers to entry. Once the determinants for collaboration in innovation processes are set, the possible alternatives (i.e. joint ventures, acquisitions, licensing etc.) are examined through an analysis of either environment specific conditions such as, for example, the "appropriability regime" (Teece, 1986), or rather the firm resource set (Roberts and Berry, 1985).

The organizational learning explanation departs from the economic nature of the determinants of a positive role of inter-organizational relationships in the development of innovation (Kogut, 1988). In particular, it claims that R&D activities are "..interacting heuristic search processes." (Nelson and Winter, 1977, p. 52) and that the very knowledge being developed is organizationally embedded. Its transfer cannot therefore be achieved through a market transaction because it is partly tacit (Polanyi, 1967). However, organizations cannot rely simply on their own internal knowledge base since the routines developed around it become embedded in the organization, constraining departures from well-known and explored paths (Nelson and Winter, 1982) and acting as filters to the introduction of innovation (Henderson and Clark, 1990). On the contrary, by widening the sources of knowledge to include external organizations, resistance created by internal structural filters would be overtaken (Kogut and Zander, 1992). Moreover, the use of collaborative arrangements allowing for mutual access to internal processes will facilitate both the development and the transfer of tacit knowledge.

Regardless of the differences in the approach to the analysis of inter-organizational relations, the three streams of research mainly focus on the conditions under which it would be appropriate for firms to engage in cooperative actions to pursue innovation. Much less attention, on the contrary, is given to the role that alternative organizational structures might have in determining the outcome of the relation (for an exception see Roberts and Berry, 1985). Even when the importance of organizational structure is recognized, such as for example within transaction cost theory, the solutions offered are not acting directly on the content of the interaction. They are rather setting the conditions for it to occur and controlling their stability over time through contractual mechanisms. It is therefore to the role of organizational design in innovative activity that I now turn in order to ground theoretically the role of inter-organizational structuring decisions.

1.1.2 Organization structure and innovative processes

Albeit almost neglected in the particular context of inter-organizational relations, the importance of organizational structure and its interaction with task characteristics is strongly rooted in the organizational theory literature. Starting from the seminal works of Burns and Stalker (1961), Woodward (1965), and Lawrence and Lorsch (1967), the contingency school developed both at the macro level, exploring the concept of fit between organizational and environment characteristics (Aldrich, 1972; Duncan, 1972; Duncan, 1976), and at the micro level, investigating the relationship between nature of the task and structural characteristics (Perrow, 1967; Allen and Katz, 1986; Larson and Gobeli, 1988).

Burns and Stalker (1961) first proposed that an organization's characteristics are a function of environmental uncertainty. Lawrence and Lorsch (1967) continued in this direction by showing how environmental conditions, and hence organizational structure, could vary within the same organization among its different units. Organizational design therefore became central, and detailed work was conducted in determining in more depth the effectiveness of different organizational forms (Galbraith, 1973; Galbraith, 1977).

Innovation development activities, i.e. activities characterized by ill-defined tasks in uncertain environments, started to attract researchers' attention. The unit of analysis was therefore shifted to a lower level, usually the single project, focusing on the differences in effectiveness of alternative solutions in the functional/project spectrum (Marquis and Straight, 1965; Larson and Gobeli, 1988; Roberts, 1988), the influence of patterns of communication on the final outcome (Marquis and Straight, 1965; Allen, 1977; Allen, 1986; Allen and Hauptman, 1987), and the role of human resource management practices (Katz and Allen, 1985; Allen and Katz, 1986; Allen and Katz, 1990).

Only recently, have the concepts developed in the contingency-approach started to be extended from the intra-organizational domain to the inter-organizational domain. At a macro level, for example, Rebentish and Ferretti (1993), studying technology transfer within international joint ventures in the chemical and steel industry, develop a model where the characteristics of the object being transferred (Transfer Scope) and the characteristics of the organizational structure used to achieve the transfer (Transfer Method) concur in determining the success of the transfer. At a micro level, Schrader (1994), shows the impact of supplier-manufacturer communication channels and responsibility on project performance in the printed circuit board industry and in the automobile industry.

This research indicates that in the analysis of inter-organizational relations it is indeed important to widen the set of governance elements considered. In particular, in addition to the commonly agreed upon contractual aspects, the structuring of the information flows and the identification of the appropriate coordination mechanisms emerge as fundamental issues to be addressed. While clearly contributing to identifying another important structuring dimension of inter-firm relations, however, approaches rooted in organization theory do not take into consideration the contractual governance mechanisms and how they relate to the alternative structuring choices.

1.2 Thesis objective and review of empirical findings

The evolution of theory and research on inter-firm relations seems to have followed two parallel tracks. On the one hand, studies on inter-organizational interactions stress the role of transaction's specific elements in determining the appropriate governance form of inter-firm relations. The emphasis is on the institutional characteristics driving the governance of task-partitioning decisions. Moreover, governance mechanisms are implicitly equated to the alternative legal forms associated with the relationship, which varies along an ideal contract-based spectrum. Differences in the level of contractual commitment are therefore used to distinguish inter-firm relations.

On the other hand, organization theorists concentrate on the implementation alternatives as a function of task characteristics. The contractual base of inter-firm relation is neglected altogether and the focus is shifted to the different dimensions of organizational design as the available alternatives to effectively structure the relationship. For example, depending on the degree of uncertainty and ambiguity of the task, the differences in the amount, type, and directness of inter-partners communication will impact positively or negatively the final outcome. Similar observations can be made with respect to the degree and amount of division of labor among two or more independent parties.

Despite these apparently unreconcilable differences, the two approaches share two fundamental elements. First, they both identify task-characteristics as an a priori for the choice among alternative governance forms and procedures. Variance in the type and form of inter-firm relations stems from variance in the task characteristics. Second, they both claim that performance differentials are a function of fit, or misfit, between the characteristics of the task and the contractual form or the structuring choices respectively. Regardless of the specific notion of performance, an issue which will be addressed later, the determinants of the ex-post likelihood of success or failure of the relation are a function of the consistency between the characteristics of the task to be partitioned and partitioning choices.

Building on these elements, a theory of inter-firm relations must address three more aspects. First, we need to articulate conceptually structuring mechanisms to encompass both contractual and organizational alternatives and their relation with task characteristics and relationships' outcome. On the one hand, an exclusive focus on the legal characteristics of the governance form chosen underscores the organizational implications of its subsequent implementation. On the other hand, the analysis of the implementation processes ignoring the related contractual aspects generates a priori an omitted variable problem.

Second, we need to operationalize these concepts to empirically test the role of structuring alternatives and offer practical insight for the management of inter-organizational relations. Different empirical specifications of contractual (ex. contract length and degree of specification) and organizational aspects (ex. frequency and timing of communication among partners) have oftentimes been used as alternative measures. To fully understand the impact of alternative relational structures, the different sources of variance must be appropriately identified and included in the estimate.

Third, the assessment of the performance implications of structuring alternatives of inter-organizational relations using traditional attribute-based models is a fundamental building block to evaluate each individual relationship. For a complete understanding of the role and implications of alternative relational strategies, however, the impact of the whole relational set in which a single actor is embedded must be considered. To do that, we must abandon attribute-based explanations and adopt a relational perspective to map and examine not just single relationships, but the whole network of ties activated by the actors observed, modeling network characteristics and testing their performance effects.

The purpose of my research is to address and articulate these three different issues. The general proposition which is tested in the dissertation can be formulate as follows: "the structure of inter-organizational relationships is a function of the characteristics of the task performed in the relationship, and the fit between these elements determines the outcome of the relationship". Figure 1.1 presents an overview of the overall structure of the dissertation. The following sections summarize the research presented in each chapter, its results, and its implications for the overall theoretical framework.

1.2.1 Structuring inter-firm relations: a multi-dimensional approach

In Chapter 2 I develop a theoretical framework presenting the contractual and the organizational governance of the relationship as two dimensions to be used to structure inter-firm relations, depending on the characteristics of the task to be partitioned. These dimensions describe the distribution of rights and the informational coordination of processes within inter-firm relationships. More precisely, (a) contractual coordination refers to the mutual exchange of rights between the parties involved in a relationship in order to govern the combination of agents or functions toward the production of results, and (b) procedural coordination refers to the mutual exchange of information for the combination of agents or functions toward the production of results.

Each relationship involving multiple actors pursuing a common goal can be characterized on the one hand by the type of contractual arrangement chosen to govern the transaction among the parties, and on the other hand by the organizational procedures used to implement the relationship. Choices along both dimensions are a function of the characteristics of the task to be partitioned. Moreover, such choices are complementary, in that they address a priori conditions for the relationship to work, as well as the process mechanisms to achieve the desired goals. What matters is therefore the congruence between a multi-dimensional context and a multi-dimensional structure, which is reflected in a systemic notion of fit between the two (Van de Ven and Drazin, 1985).

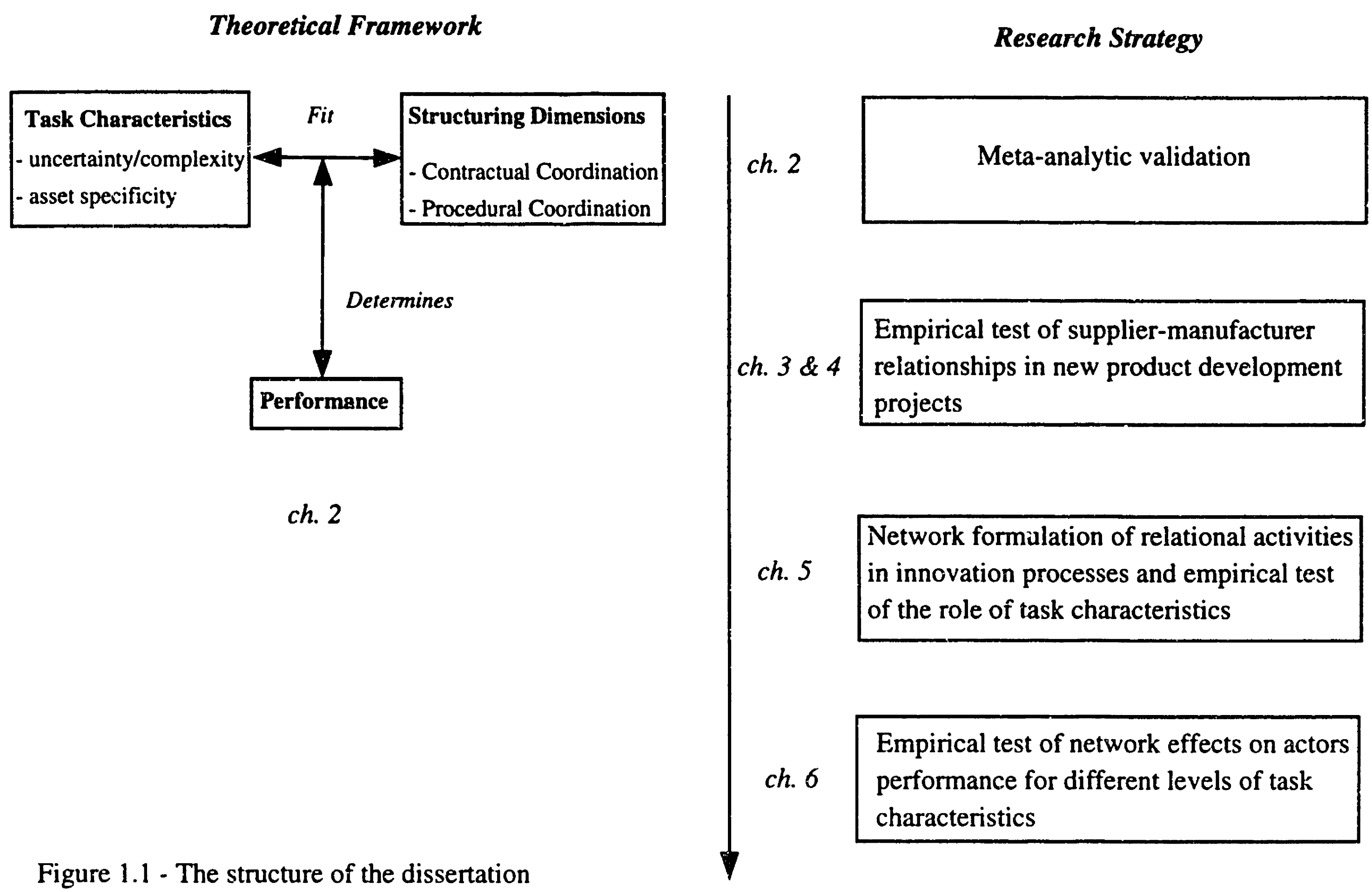


Figure 1.1 - The structure of the dissertation

I use a quantitative meta-analysis based on 55 empirical analysis of inter-organizational relations reported in 32 published articles to summarize the empirical evidence available and to test the appropriateness of the theoretical framework. Meta-analytic procedures are used to transform literature reviews from purely qualitative realms into quantitative ones. Each study reviewed is treated as an observation, and the reported significance level or effect size are used (Hunter et al., 1982; Hunter and Schmidt, 1990; Rosenthal, 1991) to compare and/or the combine the empirical evidence emerging from the studies reviewed.

In this research the studies were collected with an electronic search on ABI-Inform of the articles published in the major international management and economics journals from January 1987 to April 1994. Criteria to determine the list were (a) coverage of a broad range of disciplines, (b) differences in the targeted audiences (managerial vs. academic), (c) differences in the empirical approaches used. An informed set of keywords derived from the theoretical analysis and from reviewing some older seminal articles was used in the search, which generated a list of 118 articles. Based on the abstracts, all articles involving the analysis of interactions among non-profit organizations or focusing on university-industry relations were excluded. Articles based on secondary empirical sources to formulate prescriptive indications were also excluded. This first selection generated a list of 46 articles. Ten more articles were then added to this list after an examination of the references lists of the selected articles. After a careful reading of each of these 56 articles 32 of them were retained. The articles excluded reported results from surveys, which were not based on any theoretical framework, or were still moving on a theoretical ground limiting their empirical contribution to a purely speculative one. The empirical analyses reported in the final set of 32 articles were extrapolated in a final sample of 55 independent studies.

The results of the meta-analysis highlight several conceptual and methodological issues. First, the importance of the contractual coordination dimension is confirmed. It depends on the task-related characteristics and it affects final performance. These results are not unexpected. They strongly agree with managers' emphasis on negotiation and contracts as fundamental aspects of inter-firm relations and have long been theoretically sustained by organizational economists.

On the contrary, the evidence about the role of procedural coordination in inter-firm relations is mixed. Procedural coordination mechanisms clearly appear to influence the performance of the relationship. The empirical findings regarding the relationships between task characteristics and the level of procedural coordination, however, are more ambiguous. First, it is statistically problematic to combine the studies relating task characteristics and procedural coordination due to magnitude differences in the reported significance levels. Second, substantive concerns relating to the variance in the operationalization of the theoretical constructs used within the different studies need to be raised.

More generally, research on inter-organizational relationships seem to have followed separate and parallel tracks. On the one hand, studies focused on contractual coordination mechanisms underestimate the importance of observing variance in the procedural coordination mechanisms used in the cases observed to implement the relationship between the partners. On the other hand, studies of procedural coordination mechanisms take contractual coordination mechanisms as resulting from separate decision processes.

Moreover, neither the studies focusing on contractual coordination mechanisms nor those focusing on procedural coordination mechanisms consider simultaneously the relationship between task characteristics, coordination, and performance. The former take the performance implications as given. The latter assume that choices among structuring alternatives are unconstrained by task characteristics. This separation between the determinants of the choice among structural alternatives and the effects of such a choice is unsatisfactory. Performance implications are neglected and omitted variables raise considerable validity concerns.

1.2.2 The trade-off between efficiency and learning in inter-firm relations

The second part of the dissertation (chapter 3 and 4) presents a study designed to overcome the weaknesses emerging from the meta-analysis, encompassing within the same study the relationship between task-characteristics, the two dimensions of inter-organizational structuring, contractual coordination and procedural coordination, and performance. It operationalize these theoretical constructs in the context of supplier-manufacturer relationships, focusing on new product development activities.

Chapter 3 sets the background for the analysis reported in chapter 4. It presents an historical analysis of the co-evolution of technology and structure in the European major home appliance industry. Using archival records, the changing patterns of technological innovation and organizational structures are examined within the industry between 1945 and 1992. The analysis of the role of technological innovation in addressing organizational choices confirms the cyclical interactions between product and process innovation. Yet, it also provides additional evidence for the need for better frameworks to encompass the management of innovation processes facing at the same time the constraints of large scale manufacturing, and the opportunities of creative product differentiation. Regardless of its functional source, whether on the demand or on the technology side, mature mass-markets seem to converge consistently towards highly fragmented and temporarily unstable patterns of consumption. Contingency approaches to environment characteristics seem therefore challenged by the interdependence of previously orthogonal dimensions.

The response of European major home appliances manufacturers to these challenges has been a constant shaping of internal structures around the technological base required to achieve competitive advantage. Failures along these strategies resulted in exits at different times. The contemporary need for size and scope was not achieved merely by functional or geographical separation, but rather fostered through increased inter-unit coordination. Specific activities, such as product development, where different and frequently contradictory task characteristics are conveyed, become the institutional environment to shape the internal and external structure of the organization and to adapt it to the changed nature of the external environment.

Within such context, suppliers are called to play an ever increasingly important role. The strategic relevance of product-process interaction, the shortening product life cycles, and the need to balance volumes with product differentiation requires home appliance manufacturers to focus on processes and product architecture knowledge. Such knowledge, though, couldn't successfully be exploited without components related knowledge. External sources are therefore used more and more to complement internal competencies, subcontracting the control of parts-related knowledge domains. The internal reorganization is hence accompanied by the need to appropriately structure the supplier chain within new product development activities.

Following these observations, chapter 4 presents a study of supplier-manufacturer relations in new product development in the European major home appliance industry.

First, building on a problem solving approach to the analysis of innovative activities, the role of task characteristics in determining the outcome of the relationship is extended and specified at the relationship level. Second, the meaning of performance is discussed to distinguish among short term (efficiency) and long term (learning enhancing) effects. Third, the congruence between task characteristics and expected outcome is determined as a function of the type of inter-organizational coordination mechanisms put into place. A set of 8 hypothesis is derived and tested using data on a unique sample of 50 supplier-manufacturer relationships.

A multi-case multi-level approached was used as data collection strategy. Three product development projects conducted between 1993 and 1995 within three SBUs of one of the five largest European groups were selected with the top management to span across the innovativeness domain. Innovativeness was defined at the company level, assessing the extent to which the specific project represented a departure from existing market and technological competencies. One case is about a radical departure from existing competencies, another one is about incremental departure, and the third one lies somewhere in the middle.

Within each of the projects, data were collected during 1995 through direct interviews, the analysis of internal records and public sources, following a three-stage sequence designed to move through three different units of analysis - the SBU, the project and the single interaction with a supplier within the project. Data on the SBU and the overall projects were collected to define the background necessary to appropriately examine the specific interactions. SBU level data included general information such as size, operations, products, markets, history, as well as the technical evolution of the product portfolio and a detailed analysis of purchasing strategies. Project level data were collected to reconstruct the history of the project, both retrospectively (for the phases already concluded) and in real time (for the phases still under development). They included an analysis of the different phases, their timing and costs, an articulation of the different dimensions of the problem solving activities, which organizational units were involved and responsible during the different phases, major difficulties encountered and unresolved issues, and a judgment on the overall performance of the project both financially and organizationally. Data collection methods included direct interviews with several project members, the analysis of archival records and visits to the laboratories and pilot plants.

Data on each single relationship were collected during the third and last phase, carried through additional interviews specifically focused on the analysis of the role of suppliers within each project. The interviews were followed by the administration of structured questionnaires to collect information on the contractual and coordination mechanisms used for each single relations, as well as performance indicators, distinguishing between short term efficiency increasing effect and long term learning enhancing effects.

Using the single relationship as unit of analysis, the results show that: (1) the type of knowledge being partitioned between the supplier and the manufacturer and its level of interdependency with the rest of the project are important predictors of the outcome of the relationship; and (2) a clear trade-off between short term (efficiency) and long term (learning) effects exists. Structuring dimensions contribute differently to this processes. Contracts length, type and degree of specification vary very little among suppliers, regardless of task characteristics. On the contrary, variance in procedural coordination mechanisms is an important factor mediating between task characteristics and relationship outcome. Efficiency-oriented type of relationships require fewer coordination efforts, are initiated later during the project, communication is less frequent and occurs through non-dedicated channels, and problem solving is generally sequential rather than overlapping. On the contrary, in learning-enhancing relationships suppliers are contacted well ahead during the project and start to work in overlap with the manufacturer, generating higher levels of communication, frequently through dedicated channels.

1.2.3 Inter-organizational relations in new product development: a network approach

The analysis of supplier manufacturer relationships raises three important points. First, it showes that relational outcomes can be quite different; second, that to understand such differences it is important to focus on the specific characteristics of the activities being partitioned among the actors; third, that choices among alternative coordination mechanisms are to be examined accordingly, to determine the preferred solution for a given combination of relational characteristics and expected outcome.

These results are derived by theoretically grounding interactions among multiple agents in the information processing perspective of organizational action, with a particular focus on innovation development activities. The actors involved are faced with an incomplete information set with respect to the task at hand, and consider the access to external information sets as a way to overcome their own weaknesses. As a consequence, the characteristics of the information being traded become central in understanding the whole process and its underlying structures.

To further assess and specify the role of the characteristics of the activities being partitioned as a way to understand relational structures and outcomes, we need to elaborate the transfer process itself in relational terms. This means to go into the black box of transfer flows and examine the role of scale effects (ex. the overall amount of information being transferred) as well as scope effects (ex. the diversity of information sources), the role of direct vs. indirect access to information, and the outcome implications of alternative relational strategies.

The last two chapters of the dissertation approach these issues. Chapter 5 is dedicated to framing the problem in relational terms and testing the consistency of the results obtained previously in a different setting using a different methodology and different data-analytic techniques. Chapter 6 extends the analysis by examining the link between relational strategies and performance. For the empirical analysis I use in both chapters a unique data set, with complete relational data among 25 distinct R&D units for 173 new product development projects performed during 1994. Data are analyzed using network analysis techniques to model interactions in pure relational terms.

It is important to note how, despite the substantial changes in the research design and data analysis choices, the unit of analysis (a single relation) and the level of analysis itself (a product development project) are kept constant with respect to the study of supplier-manufacturer relations presented in chapter 4. The apparent differences in the techniques and methodologies used should therefore not underscore the continuity of the research plan carried through the dissertation.

Chapter 5 links the notion of innovation as heuristic search processes to the information processing view of organizations, articulating in relational terms procedural coordination mechanisms. Scale, scope, focus and differentiation notions of information transfer are clarified and investigated with respect to the characteristics of the transferred objects. Six propositions are derived, postulating an association between the amount of exchange among the parties (relational size), the differentiation of the relational set (relational scope) and the modes of interactions within the sets (structural patterns) and the characteristics of the task.

To operationalize these theoretical constructs I use the tools and approaches of social network analysis. First, network density and degree centrality indexes are introduced as indicators of the amount of relational activities occurring within the relational set. Second, prestige centrality and rank centrality indexes are introduced and discussed as indicators of the scope of relational activities characterizing different actors in the network. Third, sub-group analysis based on the concept of clan are presented as a way to highlight the multiplexity of the contexts of interaction among the actors in the observed set and model its structural patterns. A set of hypotheses is derived and guides the empirical analysis.

Holding contractual coordination mechanisms constant, the results show that higher levels of task complexity are associated with larger amount of transfers among the units, wider scope and multicontexutal relational sets. This is a direct empirical test strongly confirming the link between task characteristics and the choice of procedural coordination mechanisms in inter-organizational relations.

Chapter 6 builds on these results to investigate the effects of actors' positioning in the relational structure both at the individual level, and at the overall structural level, linking the fit between task characteristics and structuring dimensions to the outcome of the relationship. Network autocorrelation models (Marsden and Friedkin, 1994) are introduced to evaluate the impact on individual performance of different relational strategies, controlling for possible influences deriving from the constraints imposed by the overarching structure. Different formulations of network autocorrelation models are first introduced to ground theoretically their meaning for the analysis of inter-organizational relations in innovation processes. The choice of the mixed regressive-autoregressive model

(Doreian, 1981) is then accompanied by a technical description of the econometric specification and its underlying assumptions. The empirical indicators used in the analysis are subsequently introduced, building on the results of the previous chapters and of previous research on innovation development activities.

The empirical results (a) show the existence of a relationship between networking activities and unit's performance, and (b) how this effect is contingent upon the nature of the task performed in the relationships. Network size, scope and structural patterns - i.e. the relational representation of procedural coordination mechanisms - are considered simultaneously and their fit with the characteristics of the task performed in the relationship affects individual outcomes.

1.3 Intended contributions: theoretical and managerial implications

On a theoretical ground, the first contribution of the dissertation is the recomposition of institutional decisions driving the governance of inter-firm relations and their organizational implementation. By building on previous works in economics, strategy and organizational design, the framework developed in chapter 2 considers as fundamental elements for the effectiveness of inter-firm relations both status variables (i.e. determinants of cooperation) and process variables (i.e. procedural mechanisms to coordinate the relation). It links inter-organizational structures to the nature of the task being performed and articulates such structures into contractual and procedural coordination mechanisms. Moreover, by explicitly including organizational design constructs as moderators of the impact of inter-firm relations on the final outcome it extends the contingency approach from the intra-organizational domain to the inter-organizational domain. Not only would such an effort provide normative indications of the impact of different structuring choices on the outcome of the relations, but it would also be the basis for a theoretical assessment of inter-organizational structures.

The second contribution lays in the use the relation as the unit of analysis, within one specific activity: the development of a new product. Usually, the selection of multiple activities is driven by the implicit assumption of within-activity homogeneity with respect to the chosen attributes (e.g. uncertainty). I contend that we can observe variance within the same type of activities and that such variance should also correspond to differences in their organization. Lawrence and Lorsch (1967) idea that sub-units within the same organization are structured differently is therefore extended to the activity level, claiming that the same activity can be organized differently even within the same unit. This approach enriches the framework with the results of the literature on innovation management when several taxonomies of innovation are proposed to be related to different organizational solutions. In addition to that, it helps in setting the boundaries of inter-firm contributions. For example, if the purpose of the development project is the rejuvenation of an already existing product, suppliers' participation might be limited to meeting slightly modified engineering specifications. In contrast, substantial changes in the existing product base might require the design of completely new components. The differences in the activity observed (the development of new products) should therefore correspond to differences in inter-organizational choices.

The third theoretical contribution is the conceptual modeling of structuring alternatives using a relational perspective. While interested in the analysis of specific relations, in fact, previous studies have only indirectly derived information and provided implications on the basis of attributional analysis based on the observation of inter-subject differences, rather than by focusing on inter-relational differences. Departing from this well established tradition, the studies presented in this dissertation stress the conceptual salience and empirical relevance of choosing the appropriate unit of analysis whenever approaching the study of inter-organizational relations. The concepts of network size, scope and structural patterns are developed to model behavioral explanations for sources of organizational inertia in innovative processes and their econometric specification in network autocorrelation models provides the basis for formal tests of contextual effects on individual actions.

From a managerial perspective, the whole work aims to attract practitioners' attention to the need for a planned effort on the organizational implementation of inter-organizational relations which should simultaneously complement contractual negotiation, rather than sequentially supplement them. The empirical studies are modules stressing different aspects of this problem. The meta-analysis provides a quantitative assessment of the importance of both contractual and procedural coordination mechanisms for the success of the relationship. The analysis of supplier-manufacturer relationship in new-product development projects examines some instances at an operational level and provides practical insights of the managerial implications of changes in the object of the relation. The network analysts of inter-organizational relations in new-product development provides a direct and quantitative test of the role of fit between activity characteristics and structure on performance and offers important stimuli for the use of such techniques for organizational design interventions in inter-organizational relations.

CHAPTER 2
Structuring inter-organizational relationships: a meta-analysis

2.1 Introduction

In this chapter, I use a multi-disciplinary perspective to formulate a theoretical framework where two fundamental dimensions characterizing the structure of inter-firm relationships can be distinguished: contractual coordination and procedural coordination. Traditionally, these two dimensions relate to different streams of research (Ring and Van de Ven, 1992). Contractual coordination has been primarily investigated by research that is concerned with the distribution of rights within a relationship. Procedural coordination has been the focus of work that is concerned with how firms or organizational units align their joint processes through organizational mechanisms.

Through a an analysis of different theories of inter-organizational relations, I argue that both dimensions (a) are influenced — at least partly — by the same underlying constructs, (b) address complementary aspects of the relationship, and (c) that their fit with the characteristics of the tasks jointly performed by the partners affects the outcome of the relationship. The chapter is organized as follows. Section 2.2 elaborates the concepts of contractual and procedural coordination building on different theoretical approaches on inter-organizational relations. Section 2.3 introduces the theoretical framework. Sections 2.4 presents a meta-analysis of empirical research in inter-organizational relationships, discussing the sampling criteria and introducing the techniques used and their implications for non-experimental studies. Section 2.5 reports the results of the meta-analysis. Section 2.6 concludes discussing the use of previous research as a first validation of the framework and how the results of the meta-analysis informed the development of the research design of the studies presented in the following chapters.

2.2 Two Dimensions of Inter-firm Relationships: Contractual and Procedural Coordination

Several streams of research have investigated inter-firm relationships, concentrating on different characteristics of the relationships. Two fundamental dimensions appear to be of key importance for the governance and the management of such relationships: contractual and procedural coordination. Both dimensions characterize solutions to the coordination problem that arises when activities are distributed among several actors.[1] These dimensions describe the distribution of rights and the informational coordination of processes within inter-firm relationships. <u>Contractual coordination</u> refers to the mutual exchange of rights between the parties involved in a relationship in order to govern the combination of agents or functions toward the production of results. <u>Procedural</u>

[1] The Oxford English Dictionary defines coordination as a "harmonious combination of agents or functions toward the production of a result." Thus, the need to coordinate arises whenever a result is to be achieved by different agents or functions, as is the case in inter-firm relations.

<u>coordination</u> relates to the mutual exchange of information for the combination of agents or functions toward the production of results.

In the remainder of this section, I characterize these two dimensions building on four different theoretical underpinnings: Transaction Cost Economics, Structural Contingency Theory, Organizational Learning Theory and Resource Dependency Theory. On the one hand, contractual coordination is a core construct of Transaction Cost Economics (Williamson, 1975; Williamson, 1985). The relevant research concentrates on the governance of relationships (Anderson, 1985; Joskow, 1985; Levy, 1985; Joskow, 1987; Masten et al., 1991). On the other hand, procedural coordination is strongly embedded in Structural Contingency Theory (Burns and Stalker, 1961; Woodward, 1965; Lawrence and Lorsch, 1967; Thompson, 1967; Galbraith, 1974; Duncan, 1976) and Organizational Learning Theory (Fiol and Lyles, 1985; Levitt and March, 1988; Kogut and Zander, 1993; Nonaka, 1994). Both approaches are primarily concerned with differentiation, coordination and adaptation of behavior within organizations. Finally, Resource Dependency Theory appears to link contractual and procedural coordination (Pfeffer and Salancik, 1978; Astley and Van de Ven, 1983; Ulrich and Barney, 1984). However, the relating empirical work tends to concentrate primarily on the contractual dimension (Pfeffer and Nowak, 1976; Shan, 1991).

2.2.1 Contractual Coordination

The use of inter-firm relationships implies that at least some activities are divided up among the parties. This division of labor entails the need for coordination and reintegration. The distribution of rights among the partners is a central determinant of how coordination can occur. It affects the possibilities of each partner to control the coordination of activities occurring in the relationship. When entering a relationship each partner gives up some of his rights and gains others through either explicit or implicit contracts. The resulting allocation of rights and the institutions relating to these rights determine the governance structure.

The choice between different governance structures is the core issue investigated by Transaction Costs Economics (Williamson, 1975; 1985). In essence, Transaction Costs Economics investigates how to determine an efficient governance structure for a given transaction, by minimizing the sum of production and transaction costs. Although the term "governance structure" is frequently used in a very broad sense to encompass nearly every measure to organize, structure, and guide economic behavior, the theoretical (Williamson, 1979) and empirical (Armour and Teece, 1980; Joskow, 1985) definitions primarily refer to the contractual dimension. That is, the governance structure consists of contractually determined means to coordinate the behavior of the relationship partners.

According to this understanding, the governance structure encompasses how the partners obligate themselves to a specific course of action or establish a general commitment to a specific relationship via contractual mechanisms. When setting up a governance structure, the partners have to choose between either prescribing and enforcing specific actions or using means to create a general commitment between the partners from which desirable actions evolve (Williamson, 1983). In some cases, a general commitment to the relationship between the transaction partners can serve as a substitute and provide the necessary incentives to perform the desired actions (Parkhe, 1993). Taking an equity position in the partner, for example, can provide such general commitment.

Transaction Costs Economics proposes that the necessary degree of relationship-specific commitment depends on two aspects of the underlying transaction: asset specificity and uncertainty (Williamson, 1989).[2] Asset specificity defines the irreversibility of the investments involved. It can be related to physical as well as human capital investments. The construct uncertainty is applied to a variety of phenomena ranging from individual tasks to market conditions. One common denominator appears to be that uncertainty is negatively related to the ability to bind actors in a meaningful way to a specific course of action through contracts (Joskow, 1985; 1987).

A slightly different perspective on the question of how to govern transactions or relationships is offered by Resource Dependency Theory (Pfeffer and Salancik, 1978), which investigates which type of governance structure to chose in a specific situation. The choice criteria, however, are different, although one might argue that all of them are cost related in the long run:

> "Each interaction, though varying in legality, represents an attempt to stabilize the transactions of organizations through some form of inter-firm linkage (...). (...) organizations attempt to establish linkages with elements in their environments and use these linkages to access resources, to stabilize outcomes, and to avert environmental control." (Pfeffer and Salancik, 1978, p.144)

Similarly as in the Transaction Costs Economics, commitment to coordinated action constitutes a central construct of Resource Dependency Theory. Thus, it is no surprise that also in this context the appropriateness of specific interaction structures is again determined by the level of uncertainty and the dependence on external resources. However, whereas Transaction Cost Theory is grounded in an economic approach, the Resource Dependency

[2] Several authors use other constructs, such as ambiguity, complexity, and similarity, which are all closely related to uncertainty, depending on the definitions used. In the following section of this chapter I introduce Thompson's notion of uncertainty to clarify the possible ambiguities arising from the use of different terminology. In the meta-analysis, however, I report the results separately for each construct.

Theory is based on an organizational perspective rooted in the work of Thompson (1967). Inter-firm relations are seen primarily as organizational issues (Ulrich and Barney, 1984).

The direct consequence of this difference is the attention paid to the feasibility of a specific transaction. Transaction Costs Economics still inherits from neoclassical economics the assumption that any transaction object is perfectiy transferable (Conner, 1991). In other words, it investigates only the enforceability of a specific transaction, taking its feasibility as given. Moreover, it assumes that the output of a specific transaction is not influenced by how the transaction is structured. For example, following Transaction Costs Economics, the design of a new chassis will not differ whether it is entirely developed by a car manufacturer or jointly developed with an external design firm. Any differences between the different task partitioning will only be reflected in the final costs.

Resource Dependency Theory, on the contrary, does not assume that every transaction is feasible within a given environment. Two aspects of the feasibility are discussed (Pfeffer and Salancik, 1978, p. 143). First, for a given transaction, the existence of external constraints may inhibit its occurrence even within the most appropriate governance structure. Reasons may vary from a lack of resources to institutional decisions about agents' separation. Second, the nature of the task itself might limit the options available to govern its completion. For example, the acquisition of some assets, such as technical know-how, may require the occurrence of dense communication between the transaction partners. A governance structure that does not allow for such communication would make the transaction not feasible.

This indicates that contractual coordination, the coordination through the exchange of rights, has to be aligned with procedural coordination, that is with the coordination of processes through information exchange. In other words, concentrating on the contractual dimensions of a relationship provides a one sided view since actors can use these institutions in multiple ways. Although this is explicitly recognized by Resource Dependency Theory, the relating empirical studies focus on the contractual dimensions of relationships (see for example Pfeffer and Nowak, 1976).

2.2.2 Procedural Coordination

Contractual coordination mechanisms provides institutions for achieving incentives alignment among the partners. However, it cannot be deduced from the availability of these institutions how they are actually employed to coordinate the activities of the relationship partners. Even if two organizations have contractually agreed on powerful institutions for coordination, it does not imply that they necessarily do coordinate their actions. Doz, Hamel and Prahalad argue that the actual coordination is not achieved through contractual mechanisms but rather that it is realized by day-to-day communication of the employees involved in the activities of the relationship: "Top management puts together strategic alliances and sets the legal parameters for exchange. But what actually gets traded is determined by day-to-day interactions of engineers, marketers, and product developers" (Doz et al., 1989, p. 136).

These "day-to-day interactions" are at the core of the construct "procedural coordination". Procedural coordination describes the extent to which the parties coordinate their processes by exchanging information, which make them learn to adjust their activities to each other. Procedural coordination does not refer to institutions that may be in place to govern the relationship but asks how these institutions are used. In other words, the institutional perspective of the contractual coordination dimension is supplemented by a process oriented perspective.

The problem of how to coordinate and re-integrate the activities of several actors is tied to the core research question of Structural Contingency theory: How should an organization structure and coordinate its activities among different units given specific task characteristics and other context factors?

Tasks can be characterized along a multitude of dimensions such as resources needed and interdependency with other tasks. Building on information processing models (Galbraith, 1973), Structural Contingency approaches focus on task related uncertainty, which has been operationalized in different ways such as, for example, the volatility of the task environment (Burns and Stalker, 1961; Tushman and Anderson, 1986) or the degree of differentiation in the task environment (Lawrence and Lorsch, 1967). Among the different definitions proposed, Thompson's (1967) dual notion of uncertainty seems appropriate in this context. He distinguished between uncertainty on the actions to achieve a certain goal and uncertainty on the goal itself.[3] Taken together, these two dimensions are useful to identify how complex is the project observed, and where should the attention be addressed to obtain the expected outcome.

Depending on the combinations of the different levels of uncertainty, different organizational structures are deemed appropriate and are articulated along dimensions such as degree of formalization, level of specialization, and direction of influence (Lawrence and Lorsch, 1967; Pugh et al., 1968; Duncan, 1972). These organizational design variables characterize the mechanisms used to achieve procedural coordination between actors given a specific task partitioning. They all influence patterns of information exchange within an organization (Galbraith, 1974; Allen, 1986; Larson and Gobeli, 1988).

[3] This distinction is implicit in several contributions in the decision making tradition (Tversky and Kahneman, 1974) and has been formulated also as a distinction between uncertainty and ambiguity (Schrader et al., 1993).

Despite its focus on the intra-organizational level, the Structural Contingency perspective can be transferred to the inter-organizational level (see for example Rebentish and Ferretti, 1993; Schrader, 1994). In fact, the empirical evidence stemming out of recent studies on the impact of inter-organizational relations on actors performance (see for example Clark, 1989) points to the interrelationship between level of task uncertainty, measures for procedural coordination, and performance.

The coordination mechanisms proposed by Structural Contingency Theory are based on information exchange. For such an information exchange to be an effective coordination mechanism, the interaction partners have to adjust their cognitive frameworks and have to develop a joint language, that is, they have to engage in learning processes. This dynamic perspective has been neglected by the Structural Contingency frameworks. However, several studies on inter-firm relationships indicate that they evolve over time. Nanda and Williamson (1994), for example, show that joint ventures can serve as an instrument for companies to learn about each others skills and resources. This learning enables the companies to determine which of the partner's resources are of interest and how to value these resources.

Organizational Learning Theory, explicitly provides such a dynamic perspective. Although extremely varied in its focus and level of analysis (Levitt and March, 1988; Huber, 1991), the basic Organizational Learning question can be formulated as: How to structure or enable learning processes given the nature of the knowledge to be learned. The emphasis is once more on the nature of the task, interpreted in this case as the transfer of knowledge between two or more agents.[4] Nonaka (1994) uses two dimensions to describe knowledge: its manifestation (tacit vs. codified) and its location (individual vs. group).

[4] Following Huber (1991) I use knowledge and information interchangeably.

The first dimension can be assimilated to Thompson's distinction of the different types of uncertainty, which can be found in the other three perspectives reviewed, as the emphasis is on the specific characteristics of the task/object/action observed. The second dimension introduces from a theoretical perspective the importance of the localization of information in any transaction. Learning possibilities exist whenever knowledge is unevenly distributed. However, as von Hippel (1994) points out, an uneven distribution per se does not imply that two tasks need to be strongly coupled since some information is easily transferable whereas other information is "sticky" - i.e. context specific. Only in those cases in which information is sticky, is necessary to invest in high levels of procedural coordination mechanisms Consequently, the amount of task-related sticky information determines the choice of the procedural coordination mechanisms to be used to structure the relationship. Thus, the information location issue is isomorphic to the issue of task uncertainty.

The main difference between the Structural Contingency Theory and Organizational Learning Theory is the acknowledgment by the latter that the nature of tasks may change during learning processes. This implies that the appropriate level of procedural coordination is not a constant but needs to change as well. In other words, the search for the "right" coordination structure is doomed to be fruitless as long as it is not taken into consideration that task and structures need to adapt to each other and thus change constantly in a continuous feedback system. A similar notion has been suggested by Cainarca, Colombo and Mariotti (1992) who found that the occurrence of different types of inter-firm relationships changes during the technology life-cycle. At any given moment, however, task and structure need to be in accordance to each other.

In conclusion, both Structural Contingency as well as Organizational Learning Theory help to identify mechanisms allowing parties to coordinate their processes. These mechanisms are based on the exchange of information. The higher the level of task uncertainty, the greater the need for procedural coordination. The purpose of procedural coordination is that actors exchange sufficient information so that they can adjust their behavior in a meaningful way to each other. In other words, the level of procedural coordination can be described through the quantity and complexity of the information exchanged. Organizational Learning Theory indicates, however, that relationships should not be viewed as static entities. Rather, through ongoing learning, task characteristics change constantly. Therefore, the mechanisms used for procedural coordination have to be adjusted accordingly.

2.3 The Fit-Concept

With contractual coordination and procedural coordination two different dimensions of inter-firm relations have been identified. The first dimension relates to coordination through the exchange of rights while the second one describes coordination through the exchange of information. Several authors assume that contractual and procedural coordination are closely linked to each other (Pfeffer and Salancik, 1978; Helper, 1991). Empirical evidence, however, suggests that this is not necessarily the case. Several examples exist of firms having established a high level of procedural coordination without intense contractual coordination (Piore and Sabel, 1984; Best, 1990). Similarly, firms might set up institutions for considerable contractual coordination without establishing significant procedural coordination (Joskow, 1987).

The choice along both dimensions is related to the characteristics of the tasks performed in the relationship. Combining the different perspectives reviewed, the task domain can be articulated focusing on three aspects (table 2.1). Asset specificity determines the extent to which the activities performed in the relationships have some economic value per se or not. The higher the asset specificity, the lower the chances for the partners to benefit from their activities outside the relationship. The level of task uncertainty can be referred to the action or to the goal domain. In the first case, the partners have agreed on the objective of their relationships, but have multiple options to achieve the goal. Ring and Rands (1989), for example document how NASA and 3M were able to specify up front their goal for common projects on microgravity experiments and subsequently worked through the implementation of their collaboration. In the second case, the goal itself is unclear. These situations have been documented in many studies of collaborative R&D projects, when the partners might initiate the relationship for some generic strategic reason, but lack an operational objective (Tripsas et al., 1995).

Table 2.1 - The theoretical constructs related to the analysis of inter-organizational structuring.

Task Characteristics	*Structuring Dimensions*	
	Contractual Coordination Mechanisms	Procedural Coordination Mechanisms
- asset specificity	- type of legal agreement	- frequency of information transfer
- uncertainty in the goal	- length of legal agreement	- timing of information transfer
- uncertainty in the means	- specificity of legal agreement	- directionality of information transfer
		- means of information transfer

Given different characteristics of the tasks to be performed within the relationship, the partners structure their interaction by (a) articulating the legal conditions governing the transaction and (b) identifying the mechanisms to transfer information among to implement the transaction. Contractual coordination mechanisms are used to define the legal boundaries of the relationships (table 2.1). They involve the choice of the legal form governing the agreement (ex. joint venture or strategic alliance, equity and non equity joint venture etc.), the length of the agreement, the extent to which partners are bound to the agreement (ex. exclusivity clauses, penalties etc.) and the degree to which these choices are specific to the agreement or not (ex. standardized vs. personalized contracts).

Procedural coordination mechanisms, instead, are used to put into place the relationships within the institutional boundaries defined by means of the contractual coordination mechanisms chosen. They are targeted to the structuring of information flows between the partners (table 2.1). Decisions on the frequency, the timing, the directionality of information flows, as well as the means through which these flows occur identify the operational dimensions of procedural coordination mechanisms. For a given institutional setting defined by a specific combination of contractual coordination mechanisms, alternative choices of procedural coordination mechanisms are going to impact the outcome of the relationship differently. Carter and Miller (1989), for example, show how frequent and bilateral communication between vendors and buyers sensibly limited the occurrence of quality problems in the materials delivered.

To some extent, investments in procedural coordination mechanisms may substitute for contractual coordination mechanisms. Procedural coordination does not come for free, though. Learning has to take place, interfaces need to be established, lines of communication reorganized, etc. The investments necessary for these changes may already sufficiently commit the relationship partners to each other. Consequently, additional contractually based commitment mechanisms might not be necessary anymore. In other words, while the task characteristics may suggest that the partners should establish a high level of contractual coordination, it may actually be unnecessary to do so if the partners have already committed to each other through investing in procedural coordination.

This suggests that it is not possible to determine the optimal combination of contractual and procedural coordination given specific task characteristics alone. Several models of fit have been used to determine levels of coordination (Scott, 1990). Those models which limit their analysis to univariate context structure relations fail to account for the multidimensional nature of the context and of the structure and they do not explicitly consider performance implications (Van de Ven and Drazin, 1985). The models of fit which explicitly include performance, typically fail to consider that alternative combinations of structural dimension may have the same performance implications. They determine each structural dimension independently of the other structure dimensions without investigating possible substitution and trade-off effects.

Rather, it is more realistic to assume that several combinations of contractual and procedural coordination are equally well fitted for a given task. This notion is similar to the interpretation of fit in the systemic approach to Structural Contingency theory, where Van de Ven and Drazin use the concept of equifinality to define fit as "as feasible set of equally effective, internally consistent context-structure combinations" (Van de Ven and Drazin, 1985, p. 315).

Building on the systemic notion of fit and of equifinality, I propose to use the framework reported in figure 2.1 for the study of inter-organizational relations. The relationship between task characteristics and structuring alternatives needs to be articulated to incorporate a multidimensional combination of context and structure. Task characteristics are varied and can result in multiple combinations depending on the actors involved and on the context. Similarly, alternatives along the contractual and procedural coordination dimensions of structuring decisions can result into different outcomes, although identified to address similar task characteristics. Any full understanding of the implications and effects of inter-organizational relationship need to consider simultaneously the task domain, the structuring domain and the outcome domain, with the fit between the task domain and the structuring domain as the determinant of the observed outcome.

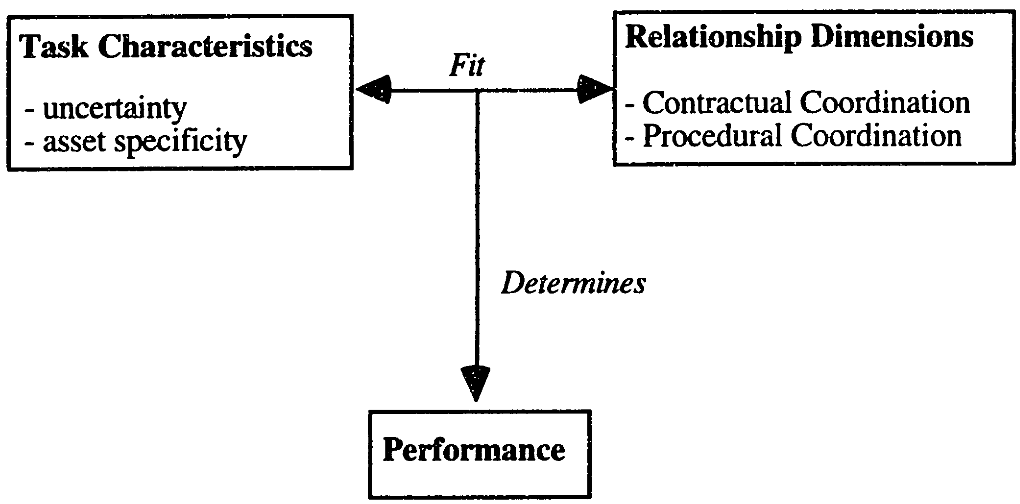


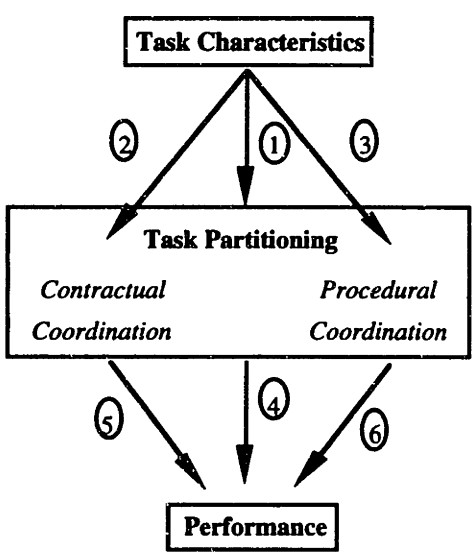
Figure 2.1 - A systemic model of fit between task characteristics, relationship dimensions and performance for inter-organizational relations

2.4 The Updated Empirical Evidence

In the following sections, I use a quantitative meta-analysis of previous empirical studies on inter-firm relationships as a first validation of the theoretical framework and to highlight possible areas of concerns in the research design. None of the studies reviewed addressed the main research question stemming out of the framework: Do combinations of contractual coordination and procedural coordination, given specific task characteristic, explain performance differentials? On the contrary, each one focused on a limited part of the whole framework. I therefore shifted the attention to each individual piece of the framework and identified 6 different research questions (figure 2.2).

2.3.1 Sample

To review the empirical results on inter-firm relations I conducted an electronic search of the articles published in the major international management and economics journals from January 1987 to April 1994. After a review of the electronic sources collecting and indexing abstracts of social science journals we decided to rely on ABI-Inform only . Certain databases are too specific (ex. Economic Abstracts), while others are too generic (ex. Lexis/Nexis). ABI-Inform, on the contrary, lists all the major social science journals, covering a broad range of disciplines.



1) Do task characteristics influence task-partitioning decisions?

2) Do task characteristics influence the level of contractual coordination in inter-organizational relations?

3) Do task characteristics influence the level of procedural coordination in inter-organizational relations?

4) Are performance differences related to task partitioning decisions?

5) Are performance differences in inter-organizational relations related to the level of contractual coordination?

6) Are performance differences in inter-organizational relations related to the level of procedural coordination?

Figure 2.2 - The research questions investigated in the meta-analysis.

The list of the journals used for the search is reported in table 2.2. Although certainly not exhaustive, it is a representative sample considering the range of disciplines covered, the differences in the targeted audiences (managerial vs. academic), and in the empirical approaches used. Moreover, the use of the file drawer procedure described below will serve as an additional check for an eventual bias in the selection process.

Table 2.2 - Journals selected for the electronic search between 1987 and 1994 on ABI-Inform

Academy of Management Executive	Journal of Law and Economics
Academy of Management Journal	Journal of Management
Academy of Management Review	Journal of Marketing
Administrative Science Quarterly	Journal of Marketing Research
American Journal of Economics and Sociology	Journal of Product Innovation Management
American Economic Review	Long Range Planning
Brookings Papers on Economic Activities	Management Science
Business History Review	Managerial and Decision Economics
California Management Review	Marketing Science
Columbia Journal of World Business	Organization Science
Decision Science	Organization Studies
Econometrica	Quarterly Journal of Economics
Harvard Business Review	R&D Management
IEEE Transactions on Engineering Management	Rand Journal of Economics
International Journal of Industrial Organization	Research Policy
International Journal of Technology Management	Research/Technology Management
Journal of Economic Behavior and Organizations	Sloan Management Review
Journal of Engineering and Technology Management	Strategic Management Journal
Journal of Industrial Economics	Technology Review
Journal of International Business Strategy	Technovation

The search was conducted using an informed set of keywords derived from the theoretical analysis and from reviewing some older seminal articles. It included the words "collaboration", "cooperation", "partnership", "alliance", "Joint Venture", "inter-firm" and was specifically addressed towards empirical pieces by also including among the keywords "data", "empirical", and "survey". The search generated a list of 118 articles. Based on the abstracts, all articles involving the analysis of interactions among non-profit organizations or focusing on university-industry relations were excluded. Articles based on secondary empirical sources to formulate prescriptive indications were also excluded. This first filtering processes reduced the original list to 46 empirical articles on inter-firm relations published during the last 8 years in the major academic journals. This list was completed by scanning the references of the selected articles and looking for those past works which were widely quoted but not included in the sample. The whole process resulted in a total of 56 articles.

After a careful reading of each of the 56 articles I retained for the meta-analysis 32 of them. In addition to the previously discussed exclusion criteria, several had to be excluded because they reported results from surveys, which were not based on any theoretical framework (for example see Kleinknecht and Reijen, 1992). Others were approaching inter-firm relationships by relating them to their external environment conditions, such as market structure, industry life cycle and the like (MacDonald, 1985; Cainarca et al., 1992), but not taking into account task related factors. Finally, others were still moving on a theoretical ground limiting their empirical contribution to a purely speculative one (Hamel, 1991).

The selected studies were grouped along the six questions presented in figure 2.2. While some of the studies were addressing more than one question, all were considering each question independently. In other words, interaction effects were not investigated. Within each group of studies, I recorded information concerning the theoretical framework used, the relevant dependent and independent constructs included in the analysis, their operationalization, the sample size, and the significance level of the results.

2.3.2 Methods

Meta-analytic procedures are used to transform literature reviews from purely qualitative realms into quantitative ones. Each study reviewed is treated as an observation, thus allowing the comparison or the combination of the empirical evidence emerging from the studies reviewed, using the reported significance level or effect size as a starting point (Hunter et al., 1982). The first purpose of any meta-analysis is to partition the overall variance observed in the reported results to partial out study-specific variance (Hunter and Schmidt, 1990). After any spurious source of variation has been partialled out, meta-analysis can be used essentially for three purposes (Rosenthal, 1991): 1) to help summarizing the evidence emerging from several studies investigating the relationship between two or more variables, as I do in this study; 2) to isolate a set of moderator variablesand verify their overall impact on the relation under study;[5] and 3) to generate hypotheses by clustering the examined studies along variables not directly observed or measured.

Despite its merits, however, meta-analysis suffers from some substantial and computational limitations (Hedges and Olkin, 1985; Rosenthal, 1991), among which three are particularly relevant in our case. First, to fully benefit from all potential outcomes of meta-analytic techniques, experimental studies with reported effect size estimates are needed. While the use of experiments is rather common in certain disciplines (i.e. experimental psychology), social sciences often focus on levels of analysis which make experiments unfeasible and the analysis of inter-firm relations is such a case. Regardless of

[5] Typical example of moderator variables in meta-analysis of psychological research are for example age and sex differences of the subjects involved in the experiments reviewed. In this case, moderator variables might be represented by the level of analysis used in the research, or the industry in which the research is performed and the like.

the perspective used, whether rooted in economics or in organization theory, we are dealing with non-experimental studies, were different covariates are often included. Because we have to accept the non-experimental nature of studies at the firm level, we are fairly limited in any meta-analysis involving comparison and combination of effect sizes.[6] I will therefore focus on the directionality and significance of the effects rather than their magnitude, and concentrate accordingly on significance levels.

Second, the same theoretical constructs are frequently operationalized and measured in many different ways. The effect that weaknesses in construct validity and reliability might have on the observed results is a common concern for meta-analysts. I address these limitations computationally in the following pages, when I discuss how I combined multi-indicator constructs and how I used and interpreted the results of multivariate procedures.

Third, meta-analysis is frequently criticized as being based on biased data sets, since the published studies are only a fraction of all the studies performed on a certain topic (the so called "file drawer problem"). Typically, the objection is that studies reporting non significant results rarely get published. While there is accordance on the other problems of meta-analysis discussed, this specific point is still harshly debated (Hunter and Schmidt, 1990; Rosenthal, 1991). On the one hand, it is argued that unpublished studies are such because inherent methodological flaws make their results unreliable and account for the weakness of their findings. On the other hand, one might argue that deviants to well established "paradigms" are more likely to encounter resistance within the scientific community, and therefore are less likely to be published.

[6] Obtaining indicators partialling out the effect of covariates might be impossible depending on the type of results reported. In addition, the presence of difference covariates in the different studies reviewed will increase the magnitude of the problem (Rosenthal, 1991, ch. 2).

Both positions focus on the possible reasons for the presence of a high number of unpublished studies. Whatever these reasons are, however, one would like to estimate their potential impact on the external validity of the results of the meta-analysis. Rosenthal (1991, p. 103-109) has recently proposed to approach this issue by calculating how many studies reporting non significant results, or even results contradicting theoretical predictions, need to be laying in some drawers waiting publication for the conclusions reached by the meta-analysis to be invalidated. The higher the number of unpublished studies needed to invalidate such conclusions, the smaller the selection bias and the greater the generalizability of the results (see also Hunter and Schmidt, 1990, ch. 13). In this analysis I use the statistical procedures introduced by Rosenthal to assess the external validity of the results.

As the first step of the analysis, I recorded from each study the one-tailed p-value associated with the reported test and found the corresponding standard normal deviate (Z). The sign of the Z-score was determined by whether the empirical evidence supported the underlying theory or not. If the theory was supported, the Z-score was recorded as positive. If it was not supported, the Z-score was recorded as negative.[7] For example, Transaction Cost Economics predicts that if asset specificity is high, task partitioning will be low. Results showing a negative association between the two constructs were coded as supporting the theory, while results showing a positive association were coded as not supporting the theory.[8] If p-values were not available or reported only as threshold levels

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[7] For example, suppose to observe an effect statistically significant at $p=.05$. Its corresponding Z-score will be +1.645 if the effect is in the direction predicted by the theory, and -1.645 if the effect is not in the direction predicted by the theory.

[8] An alternative in the comparison of studies providing results in opposite directions is to use the indications emerging from the whole set to make choices as to the directionality issue. For example, if the majority of the study reviewed show a negative association between X and Y, all the positive ones will be

(e.g., $p<.05$), I used the reported t-statistic and found the exact p-value using the associated distribution.

Whenever more than one indicator was used in the study reviewed for a specific construct I first determined the standard normal deviate (Z) corresponding to the p-value associated with each indicator. The Z's were then averaged to calculate the corresponding p-value.[9] The same procedure was used whenever more than one analysis was performed on the same functional relationship within the same study and on the same sample.[10] Analyses on different samples performed within the same studies, however, were treated as fully replicated designs, and therefore as independent observations.

To compare the studies reviewed along their probability levels I tested for the heterogeneity of the corresponding Z's (Rosenthal and Rubin, 1979). In particular, given N equal to the number of studies reviewed, Z_i the standard normal deviates computed as described above, Z_μ the average of the Z_i, I computed the following test, which is distributed as χ^2 statistic with N-1 degrees of freedom:

$$\sum_{i=1}^{N}(Z_i - Z_\mu)^2 \qquad \text{Test of Heterogeneity of the Probability Levels} \qquad (1)$$

If the results were not homogenous, the studies were carefully investigated individually to identify possible causes for the discordance of the results. In case of

coded as negative, and vice versa. Since I am testing specific theoretical predictions, however, I did not use this coding schema.

9 This procedure to combine a set of results from a single study is suggested by Rosenthal (1991, p. 27-28). Other methods involve the weighting of the different set of results according to some objective criterion or following specific statistical procedures such as the one based on Bonferroni adjustments of probability levels, but I did not deem them appropriate in this context.

10 For example, a standard procedure in economic research is to present and estimate different functional forms associated with the model developed and compare the emerging results. In this case, I considered each estimate as a single set of results and combined them all (see Hunter et al., 1982, ch. 5).

accordance, I tested whether it was highlighted because of chance alone or rather because of an underlying pattern in the population. When finding accordance with respect to the results obtained, I was then interested in assessing whether the accordance was systematic or random. For this purpose, I combined the results.

The logic of the combining step is the usual one of statistical testing. The purpose is to get an overall estimate of the probability that the p-values of the studies reviewed might have been obtained if the null hypothesis of no relation between the variables observed were true. Different tests are available for combining independent probabilities obtained from two or more studies testing the same directional hypothesis (Rosenthal, 1978). Each one presents advantages and disadvantages. Given the limited number of studies I am dealing with, I avoided to rely on a single test, and used more than one to combine probabilities obtained from the review. Table 2.3 reports the tests used, their computation and a brief description of their advantages and disadvantages.

All these tests require that the studies reviewed employ quantitative analysis methods. Any evidence emerging from qualitative studies would therefore be lost. Yet, in social science research qualitative methodologies are frequently used. In this sample, for example, studies use firm level cases (see for example Bertodo, 1990) or industry level longitudinal analysis (see for example Pisano, 1991). To benefit from their results as well, I included each of these studies in the appropriate group/s and coded their result with respect to their theoretical expectations. Combining this information with that previously recorded for the quantitative studies, I derived for each group the number of studies that showed results in accordance with the theory and the number of studies that did not, assessing the likelihood that the distribution of results could be obtained by chance alone.[11] While less accurate, this procedure allows the inclusion of qualitative results in the analysis.

Table 2.3 - Description of the methods used to combine the results of the studies reviewed.

Test	Computation	Advantages	Limitations	Reference
Adding p's	$p = \frac{(\sum p_i)^N}{N!}$	Has considerable power and needs a very limited amount of information.	When the number of studies reviewed (N) is large and/or the numerator is >1, tends to be too conservative.	(Edgington, 1972a)
Adding t's	$Z = \frac{\sum t_i}{\sqrt{\sum[df_i/(df_i-2)]}}$	Is unafftected by N, given a minimum df per study.	The studies reviewed should have many df.	(Winer, 1971)
Adding Z's	$Z = \frac{\sum Z_i}{\sqrt{N}}$	Very simple to apply and always applicable.	N should not be too small	(Mosteller and Bush, 1954)
Testing Mean p	$Z = (0.5 - p_\mu) * \sqrt{12N}$	Simple	N of studies should not be less than 4	(Edgington, 1972b)
Testing Mean Z	$t = \frac{\sum Z_i / N}{\sqrt{S^2_{(Z)} / N}}$	No assumption of unit variance	Low power when N of studies small	(Mosteller and Bush, 1954)

Source: Adapted from Rosenthal (1991, p. 98)
Note: p_i is the p-level reported by study i, N is the number of studies reviewed, p_μ is the average p-value of the N studies reviewed, t_i is the t-statistic reported by study i, df_i are the degrees of freedom of study i, Z_i is the standard normal deviate corresponding to the p-level reported by study i.

Finally, to approach the "file drawer problem" I followed the procedure recommended by Rosenthal (1991, p. 103-109). The purpose was to estimate the number of unretrieved studies averaging null results which should exist if the results obtained from the retrieved studies were due to chance alone. Technically I needed to calculate the number of unlocated studies averaging null results to bring the significance level of the

[11] I use the binomial probability theorem to find the probability of k successes (with k equal to the number of studies supporting the theory) in n trials (with n equal to the number of studies reviewed).

combination test down to .05. Given N the number of studies reviewed, Z_μ the average of the Z_i obtained from each of the retrieved studies, I used the following to compute x, the number of studies to be exceeded to invalidate the results:

$$x = \frac{N}{2.706}\left[N(Z_\mu)^2 - 2.706\right] \qquad \text{File Drawer Test} \qquad (2)$$

2.5 Results

A first reading of the empirical studies collected for the meta-analysis reveal the absence of an integrated perspective considering simultaneously the relationships between task characteristics, the contractual and procedural dimensions of inter-firm relationships, and the outcome of the relation. While studies on inter-firm relations are numerous, they are parsimonious and diversified in aim and scope. Table 2.4 lists all the studies reviewed, the dependent and independent constructs, the theoretical predictions as to the directionality of the effects, the directions of the effects observed in the empirical analysis, the corresponding p-values and the degrees of freedom used in the empirical analysis. The studies are grouped by the 6 questions previously discussed, each one addressing a separate relation highlighted by the theoretical framework. In particular, among the studies using quantitative methodologies, 6 examined the relationship between task characteristics and level of contractual coordination, 9 the relationship between task characteristics and procedural coordination, 5 the relationship between level of contractual coordination and performance of the relation, and 8 the relationship between organizational coordination and performance of the relation.

The remaining 20 studies using quantitative methodologies, while often declaring to be approaching a specific part of the framework, present results on the more general questions linking task characteristics and task partitioning decisions (18 studies), and linking task partitioning and performance (2 studies). The first evidence emerging from the analysis is the heterogeneity of the significance levels reported in the studies investigating the relationship between task characteristics and task partitioning. A visual inspection of the data reported in Table 2.4 for the studies addressing Question 1 shows a general accordance between theoretical predictions and empirical observations. This is confirmed by the binomial probability test ($p<.001$). The heterogeneity test, however, reveals that the p-values are statistically different ($\chi^2 = 11.82$, df = 17, $p<.01$). The separate use of several different constructs to assess task characteristics might account for the detected heterogeneity. A further analysis at the construct level confirms this intuition. While significance levels of studies investigating the relationships between complexity and task partitioning ($\chi^2 = 5.03$, df = 4, n.s.), similarity and task partitioning ($Z = 0.94$, n.s.) and ambiguity and task partitioning ($Z = 0.74$, n.s.) are homogenous in magnitude, heterogeneity strongly emerged with regards to the relationship between asset specificity and task partitioning ($\chi^2 = 18.56$, df = 6, $p<.01$) and uncertainty and task partitioning ($Z = 2.76$, $p<.01$).

Table 2.4 - Summary of the studies reviewed.

Research Question	Study reviewed	Independent Construct	Exp. dir.	Obs.dir.	p-value one-tailed	df
1) Do task characteristics influence task-partitioning decisions?	(Anderson and Schmittlein, 1984)	Ambiguity	-	-	.00360	158
	(Anderson, 1985)	Ambiguity	-	-	.00009	152
	(Monteverde and Teece, 1982)	Asset Specificity	-	-	.00019	124
	(Monteverde and Teece, 1982)	Asset Specificity	-	-	.00057	124
	(Monteverde and Teece, 1982)	Asset Specificity	-	-	.00102	124
	(Anderson and Schmittlein, 1984)	Asset Specificity	-	-	.01629	138
	(Anderson, 1985)	Asset Specificity	-	2 out of 3 -	.41034	152
	(Levy, 1985)	Asset Specificity	-	3 out of 12 -	.73130	64
	(Masten et al., 1991)	Asset Specificity	-	3 out of 6 -	.39942	65
	(Harrigan, 1986)	Complexity	-	-	.02500	191
	(Masten et al., 1991)	Complexity	-	3 out of 3 -	.02199	65
	(Monteverde and Teece, 1982)	Complexity	-	-	.00076	124
	(Monteverde and Teece, 1982)	Complexity	-	-	.00025	124
	(Monteverde and Teece, 1982)	Complexity	-	-	.00028	124
	(Masten et al., 1991)	Similarity	+	2 out of 2 +	.05744	65
	(Walker and Weber, 1984)	Similarity	+	+	.20611	34
	(Balakrishnan and Wernerfelt, 1986)	Uncertainty	+	+	.00415	275
	(Walker and Weber, 1984)	Uncertainty	+	+	.49042	34
	(McMillan, 1990)	Asset Specificity	-	-	*	*
	(Pisano, 1991)	Asset Specificity	-	-	*	*
	(Pisano, 1991)	Uncertainty	+	+	*	*
2) Do task characteristics influence the level of contractual coordination in inter-organizational relations?	(Heide and George, 1990)	Ambiguity	+	+	.04034	134
	(Heide and George, 1990)	Asset Specificity	+	+	.05064	134
	(Joskow, 1987)	Asset Specificity	+	9 out of 9 +	.00001	270
	(Joskow, 1987)	Asset Specificity	+	18 out of 18 +	.00001	163
	(Shan, 1991)	Dependence	+	+	.04396	126
	(Shan, 1991)	Dependence	+	+	.05029	32
3) Do task characteristics influence the level of procedural coordination in inter-organizational relations?	(Heide and Miner, 1992)	Ambiguity	+	3 out of 4 +	.39471	128
	(Heide and Miner, 1992)	Ambiguity	+	2 out of 4 +	.66472	39
	(Heide and Miner, 1992)	Asset Specificity	+	4 out of 4 +	.12016	128

Table 2.4 - continued

Research Question	Study reviewed	Independent Construct	Exp. dir.	Obs.dir.	p-value one-tailed	df
3) Do task characteristics determine the level of procedural coordination in inter-organizational relations?	(Heide and Miner, 1992)	Asset Specificity	+	3 out of 4 +	.33821	39
	(Heide and George, 1990)	Asset Specificity	+	2 out of 2 +	.00005	134
	(Heide, 1994)	Complexity	+	+	.00192	141
	(Heide and Miner, 1992)	Dependency	+	1 out of 4 +	.63297	128
	(Heide and Miner, 1992)	Dependency	+	1 out of 4 +	.77783	39
	(Heide, 1994)	Dependency	+	+	.00072	141
4) Are performance differences related to task-partitioning decisions?	(Armour and Teece, 1980)	Task Partitioning	+	+	.04872	201
	(Clark, 1989)	Task Partitioning	+	+	.08842	22
5) Are performance differences in inter-organizational relations related to the level of contractual coordination?	(Harrigan, 1986)	Commitment through non recoverable investments	+	+	.00500	191
	(Hakansson, 1993)	Ex-Ante Safeguard Definition	+	4 out of 4 +	.08262	25
	(Parkhe, 1993b)	Ex-Ante Safeguard Definition	+	2 out of 2 +	.01167	106
	(Bucklin and Sengupta, 1993)	Centralization	-	3 out of 3 -	.00565	89
	(Hakansson, 1993)	Ownership Form	+	4 out of 4 +	.18363	25
6) Are performance differences in inter-organizational relations related to the level of procedural coordination?	(Anderson and Weitz, 1989)	Communication	+	2 out of 2 +	.02003	683
	(Anderson and Narus, 1990)	Communication	+	2 out of 2 +	.02500	614
	(Carter and Miller, 1989)	Communication	+	+	.00700	393
	(Parkhe, 1993a)	Communication	+	+	.00500	111
	(Anderson and Narus, 1990)	Coordination	+	2 out of 2 +	.02500	614
	(Hakansson, 1993)	Coordination	+	4 out of 4 +	.14838	25
	(Parkhe, 1993a)	Coordination	+	+	.00500	111
	(Noordewier et al., 1990)	Oc	+	2 out of 3 +	.09566	130
	(Morris and Hergert, 1987)	Oc	+	+	*	*
	(Alter, 1990)	Coordination	+		*	*
	(Bertodo, 1990)	Coordination	+		*	*
	(Bertodo, 1990)	Communication	+		*	*
	(Thomas and Trevino, 1993)	Communication	+		*	*

* Qualitative study. Statistics not available.

Table 2.5 - Quantitative meta-analysis: Comparison and Combination of significance levels.

Research Question	Comparing[a]		Combining						File Drawer Test[e]
	Test	Result	Test					Result	
			Adding p's[b]	Adding t's[c]	Adding Z's[c]	Mean p[c]	Mean Z[d]		
1) Do task characteristics influence task-partitioning decisions?	χ^2_{17}=33.07 p=.011	The studies reviewed may not be combined	-	-	-	-	-	Relation not confirmed	-
2) Do task characteristics influence the level of contractual coordination in inter-organizational relations?	χ^2_5 = 11.24 p=.047	The studies reviewed may not be combined	p<.001	6.65 p<.001	7.10 p<.001	3.63 p<.001	-	Relation confirmed	88
3) Do task characteristics determine the level of procedural coordination in inter-organizational relations?	χ^2_8 = 24.44 p<.01	The studies reviewed may not be combined	-	-	-	-	-	Relation not confirmed	-
5) Are performance differences in inter-organizational relations related to the level of contractual coordination?	χ^2_4 = 2.25 p=.69	The studies reviewed can be combined	p<.001	4.18 p<.001	2.69 p<.01	3.42 p<.001	-	Relation confirmed	30
6) Are performance differences in inter-organizational relations related to the level of procedural coordination?	χ^2_7 = 2.27 p=.94	The studies reviewed can be combined	p<.001	6.45 p<.001	5.04 p<.001	4.76 p < .001	9.31 p < .001	Relation confirmed	87

[a] H_0: The significance levels of the different studies reviewed are homogenous.

[b] Probability that the significance levels obtained by the studies reviewed are due to chance.

[c] H_0: The significance levels of the different studies reviewed do not reflect a population pattern, Z-test.

[d] H_0: The significance levels of the different studies reviewed do not reflect a population pattern, t-test.

[e] Number of studies reporting results disconfirming theoretical predictions necessary to invalidate the analysis performed.

These results are somehow unexpected. There seems to be a diffused agreement about the role played by asset specificity and uncertainty in determining how and if tasks are split among multiple actors. The low number of studies reviewed for each of the constructs, however, suggests caution in the interpretation of these findings. Yet, such theoretical agreement is often challenged by the operationalization of different types of asset specificity (i.e. human resource, location and physical asset specificity) with the same indicator.

The observed heterogeneity might therefore derive from operationalizations which fail to distinguish the different components of asset specificity. Similarly, in the case of uncertainty the resulting contradictory evidence might derive from an unclear distinction between environment related uncertainty and task related uncertainty. Indeed, while Balakrishnan and Wernerfelt (1986) carefully distinguish between environmental and task related uncertainty, focusing only on the second one, Walker and Weber (1984) confound an indicator of environmental variability indicator (the expected rate of future technological change) and an indicator of task related uncertainty (the amount of expected changes in components), using the former to measure the latter. More generally, the analysis at the construct level suggests the need for a closer look at the individual studies reviewed whenever heterogeneity is detected.

The evidence for a relationship between task characteristics and level of contractual coordination, addressed by the studies grouped under question 2, seems to be similar to what emerged with regards to question 1. While all studies show agreement between expected and observed direction of effect (binomial probability test, $p<.001$), the comparison of the significance levels reported by each study detects heterogeneity of such significance levels ($\chi^2 = 11.24$, $df = 5$, $p<.05$). A further inspection of the p-values reported by each study shows that the cause of this result is the magnitude of the discrepancies among the four studies reviewed. In 4 out of 6 studies the p-values are at or just below the .05 level, while 2 are much smaller (around .00001). The detected heterogeneity therefore does not prevent the combination of the studies, since there is agreement in the directionality of the effect, and each study also statistically confirms the presence of an effect. Despite the low number of studies reviewed (6), all the different combining procedures used confirm the generalizability of the results observed in the sample (see table 2.5), pointing to a relationship between task characteristics and level of contractual coordination. Moreover, according to the "file drawer test" there should be a very high number (more than 87) unpublished studies reporting findings disconfirming the theoretical predictions to invalidate this conclusion.

The meta-analysis, however, does not provide evidence for a relationship between task characteristics and procedural coordination mechanisms. Already a visual inspection of the studies listed in Table 2.4 shows discrepancies between theoretical predictions and empirical results. The binomial probability test confirms these indications with a value of .05. In addition, the p-values of 5 out of 9 studies are all fairly large, ranging from roughly .4 to roughly .8. Accordingly, the heterogeneity test finds a significant difference among the p-values reported by the studies ($\chi^2 = 24.44$, df = 8, $p<.01$). Further analysis at the construct level shows that the detected heterogeneity also holds for the relationship between asset specificity and procedural coordination ($\chi^2 = 11.18$, df = 2, $p<.05$), and for the relationship between dependency and procedural coordination ($\chi^2 = 13.38$, df = 2, $p<.01$). The concerns previously raised about the operationalization of asset specificity find here a first tentative confirmation. In addition, the studies addressing question 3 are relying on a fairly low number of observations which limit their power. The lack of power might also account for the results regarding the relationship between ambiguity and procedural coordination, which are statistically homogeneous, but clearly not significant, although generally in the predicted direction (Z = 0.29, n.s.).

The relationship between task partitioning in general and performance addressed by the studies investigating Question 4 is supported by the meta-analysis. Both Armour and Teece (1980) and Clark (1989) independently conclude, working at different levels of analysis, that task partitioning increases performance levels (innovativeness in the first case, product development efficiency in the second case).[12] These results were confirmed when I examined at a more detailed level the relationship between each of the two dimensions of task partitioning and performance levels.

In answering question 5 I found evidence for homogeneity of the findings reviewed as to the relationship between levels of contractual coordination and performance (χ^2 = 2.25, df = 4, n.s.). Combining tests confirmed the generalizability of that conclusion and the file drawer test indicated that 30 unpublished studies reporting results in the opposite direction would be needed to falsify this conclusion (see Table 2.5).

Similar results emerged when reviewing the studies investigating the relationship between procedural coordination and performance. The p-values of the 8 studies addressing Question 6 were not heterogeneous (χ^2 = 2.27, df = 7, n.s.) and could therefore be combined to test for their generalizability. The different combination tests strongly confirm that the significance levels of the studies reviewed are not homogeneous in magnitude and direction by chance alone. Furthermore, the file drawer test indicates that a large number of unpublished studies, more than 85, reporting results in the opposite

[12] Due to the very small number of studies (2) addressing this issue I do not provide any quantitative test of their results.

direction would be needed to falsify this conclusion. I can therefore conclude that there is strong evidence for a relationship between procedural coordination and performance.

2.6 Discussion and implications

The quantitative meta-analysis of 32 studies presented in this chapter supports the overall structure of the proposed theoretical framework linking task characteristics to relationship structure and performance. While none of the analyzed studies investigated simultaneously all the different aspects of the framework, the cumulative logic of meta-analysis allows one to confirm the framework as a whole.

Contractual coordination mechanisms are an important dimension to structure inter-organizational relationships. Their choice depends on the task-related characteristics and it affects final performance. The evidence about the role of procedural coordination mechanisms, on the contrary, is mixed. They clearly appear to influence the performance of the relationship. The empirical findings regarding the relationship between task characteristics and the level of procedural coordination, however, is more ambiguous. First, it is statistically problematic to combine the studies relating task characteristics and procedural coordination due to magnitude differences in the reported significance levels. Second, substantive concern relating to the variance in the operationalization of the theoretical constructs used within the different studies need to be raised.

Neither the studies focusing on contractual coordination mechanisms nor those focusing on procedural coordination mechanisms, however, considered simultaneously the relationship between task characteristics, coordination, and performance. The research focusing on how task characteristics impact coordination, i.e. the structuring of a relationship, takes the performance implications as given. And the research investigating how the structuring impacts performance, assumes that choices among structuring alternatives are unconstrained by task characteristics. This separation between the determinants of the choice among structural alternatives and the effects of such a choice is unsatisfactory. Performance implications are neglected and omitted variables raise considerable validity concerns.

(a) Neglected performance implications: Research investigating the correspondence between task-characteristics and contractual or procedural coordination mechanism use the same assumption as traditional context-structure models (Van de Ven and Drazin, 1985; Scott, 1990). Typically, these models test the fit between context and structure through correlation analysis of these constructs, not including any measures on performance or any interaction terms (Joskow, 1987; Heide and George, 1990; Shan, 1991; Heide, 1994). Decision makers involved in the choice among different structural alternatives are therefore not provided with any evidence on whether certain solutions are chosen because they are indeed the most appropriate ones, or rather because they are, for example, an institutionalized response. In other words, this research does not give any guidance regarding the structuring of relationships that goes beyond the repetition of existing patterns.

(b) Omitted variables: Research investigating the influence of contractual or procedural coordination on performance typically limits its investigation to one of the coordination mechanisms neglecting the other. From this, omitted variable biases can arise. Empirically, contractual and procedural coordination are not orthogonal (see for example Parkhe, 1993). Consequently, limiting the research to only one coordination mechanism at a time is an inappropriate simplification, and it is not clear whether the results are valid. From a managerial perspective, this approach legitimizes an apparently inappropriate separation of the contractual and the procedural aspects of relationships.

In the following chapters I presents three empirical studies designed to test the theoretical framework developed in the first part of this chapter, avoiding these biases. Task characteristics, contractual coordination mechanisms and procedural coordination mechanisms are operationalized in the context of inter-organizational relationships in new product development. Their fit is then related to the outcome of the relationships observed, articulating different measures of performance.

CHAPTER 3
The co-evolution of technology and structure in the European major home appliance industry: 1945-1988

3.1 Introduction

In 1878 at the fifth World Industrial Expo in Paris several industrially produced mechanical devices, marketed as "the first real women's mechanical servants", designed to help women in daily activities were presented (Faravelli Giacobone et al., 1989). Steam-based kitchens ingeniously crafted to cook more than one dish at a time in iron cylinders hermetically closed and with steam-exhaustion valves, predecessors of pressure cookers, or the portable hot-air oven, were only some of the revolutionary inventions presented to ease the burden of domestic life.

More than a century after that pioneering exhibit, in 1986, Motorola Inc. and the Frank Lloyd Wright foundation presented the results of a ten-year project started in 1977. At the core of the project was the realization of a new type of house with electronic technologies responsible for an harmonization of the inside and outside environment. Electronic devices were at the heart of the two story building near Phoenix in Arizona, where solar panels powered a centralized computer system controlling a set of localized microchips dedicated to specific appliances and to the general regulation of the different functional aspects (i.e. lighting, data communication from and to the house etc.).

As much as in 1878 the idea of a gas stove might have sounded bizarre, dangerous and far away from its adoption by a multitude of house-holds, in 1987 the computerized system controlling the lighting of the whole house and coupling it to the stereo devices and the phone systems still seemed more a solution for high-tech millionaires rather than a promising mass-market product. Yet, around 1885 gas stoves began to be offered at affordable prices and started their diffusion challenged in the beginning of the 20th century by the substitution of gas with electricity. Similarly, remote-controlled systems to regulate the lighting of the apartments and coupled with the TV set and the stereo-system have recently reached the consumer market and are offered by high-end specialists.

The century between the Paris exhibition and the electronic house has clearly been characterized by important changes in the organization of the daily home activities in several ways and one industry has grown out of such changes: the home appliance industry. From its initial phases at the beginning of the century primarily in the U.S., the industry focused on the application of automated solutions to the execution of manual tasks in the daily life. Although not regarded as the industry of industries (Womack et al., 1990) the effects of the home appliance industry and of its products on the changes of lifestyles and daily activities have been probably as profound as the diffusion of the car as the private means of transportation. In 1991 48 millions of refrigerators and 41 millions of washing machines were produced in the world (United Nations, 1991). Together, U.S. and EU based companies account for 35% of production of refrigerators and 46% of production of washing machines. Japanese and Korean companies account for 11% and 7% respectively of production of refrigerators and for 14% and 7% of production of washing machines.

Such impact of home appliances both in the private domain and in the industrial domain of the more advanced economies suggests to focus the attention further down on the industry itself. In particular, a deeper analysis of the evolution of the major home appliance industry in Europe presents several elements of interest.[1]

First, the structural changes of competition after the W.W.II show strong similarities among the different countries. From initially stable oligopolistic structures, the post-war years of reconstruction and investments coupled with the retreat of the major U.S. producers who decided to concentrate on their fast growing and much more homogenous internal market, favored several new entrants, often specialized on specific product lines and segments of the consumer market. This period of turmoil competition didn't last too long though, and was followed by national oligopolies in the late '60s and early '70s, when the internationalization of the industry from the producer side started the process which led to the present oligopolistic structure at the European level, reached primarily by external rather than internal growth.

Second, despite the changes on the producers side, which were reflected in the consumer market through substantial price reductions, wider choice and brand proliferation, inter-country differences still remain quite consistent. The market of washing machines is a good example of such differences. Considering the two main product features of a washing machine, spin-speed and loading, European consumers still strongly differ in preferences, reflecting historical tendencies and habits and demonstrating resistance to the homogenization of consumption patterns (Baden-Fuller and Stopford,

[1] The home appliance industry usually embraces two macro-subsectors: the major home appliances industry and the small appliances industry. The major home appliances industry comprises self-standing domestic electric appliances, namely refrigerators, washing-machines, dryers, dishwashers, stoves, ovens and cooking devices. The small appliances industry comprises all the small appliances from electric razors to coffee grinders.

1991). In France, top-loading models account for roughly 70% of the market, while in the rest of Europe they are mainly considered as niche markets. Northern countries prefer higher spin-speeds, between 600 and 800 r.p.m., most likely expressing the need for more effective spinning cycle to reduce drying times. On the contrary, southern countries address their choices towards front-loading machines with lower spin-speed and are still resistant to drying functions.

Third, the changing role of technology in the evolution of the industry represents on one side a paradigmatic case of product-process interaction, on the other side an important viewpoint to observe the co-evolution of technology and structures. From an initial effort on product features characterizing the early post-war years, investments in process technologies became fundamental to reach and exploit economies of scale factors and leverage cost advantages to expel less efficient players. With higher concentration and internationalization of operations, however, uncoupled innovation efforts on products and processes are not viable anymore. On the one hand, in fact, higher volumes require substantial investments in production capacity. On the other hand, these volumes are still all but homogenous in their technical characteristics. Coordinated efforts on both the product and the process side are therefore needed to achieve successful flexible specialization modes of production in order to concentrate production efforts and at the same time guarantee a differentiated offer. Structuring choices reflect these needs and process-based solutions emerge as the only viable alternative to reconciliate the asymmetries.

Fourth, the profound differences of local markets and the contemporary concentration on the producer side are reflected in changes of organizational structures. On the one hand, the peculiarities of local markets would suggest a divisionalized structure with local SBUs and a centralized unit to coordinate and provide the central staff services. On the other hand, national volumes in many cases proved to be insufficient to sustain dedicated manufacturing facilities. While a pure globalization is frustrated by the fragmentation of the demand patterns, a classical internationalization mode faces the threats of higher costs and lower margins. Concentration and growth at the European level therefore occurs not through direct foreign investments but rather through acquisition of troubled competitors. Firms do not gain market share directly, but they buy it out indirectly and are then faced with a contingent proliferation of brands within the same group. Interesting solutions are found through more flexible organizational structures, with formal separation of technical and marketing function by product types and strong internal networking to achieve coordination (Goshal and Haspeslagh, 1990).

Fifth, the strategic decisions on the appropriate organizational structure and on the processes used to manage the changing needs of innovation processes can also be observed with respect to the type and goals of inter-organizational relations activated in the different periods. Horizontal relations are initially a way to integrate product and market offers, from which concentration processes emerge via mergers and acquisitions targeted to intangible assets such as brands and technological competencies, rather than manufacturing capacity. Vertical relations move during the years from pure purchases from a generic suppliers base, to intense collaborative relationships with specialized components and subsystem manufacturers. As innovation efforts converge towards a systemic approach to product development and engineering, joint product development activities become a key source of competitive advantage.

In this chapter, using publicly available data I present an historical analysis of the European White Goods industry exploring these different points and illustrating the evolutionary processes through which the industry has reached the present structure and characteristics. This analysis is instrumental to show why the industry and its innovative processes are particularly suited to study inter-organizational relationship in new product development projects. The rest of the chapter is organized as follows. Section 3.2 is dedicated to a detailed analysis of the evolution of the Industry from the World War II to the beginning of the '90s. Section 3.3 and 3.4 analyze respectively how technology and internal organizational structures co-evolved with changes at the industry level. Section 3.5 summarizes the elements highlighted and examines them in the context of inter-orgnizational relationships.

3.2 The evolution of the industry

At first sight, the historical evolution of the European Major home appliances industry conforms to traditional life-cycle models (Utterback and Abernathy, 1975; Hannan and Freeman, 1977; Jovanovic, 1982). Initial stages are characterized by several new entrants and a high level of competition, subsequently followed by selection processes and increasing market concentration. Similarly to other industries, such as for example the Automobile industry or the Steel industry, limited potentials for growth emerge in the long run, constraining competitors to stagnant maturity of products and markets. De-maturity phases are then reached through investments in product or brand differentiation. Despite commonalties in the stages of evolution, though, a more careful reading of the events unveils several interesting elements.

3.2.1 The fragmented post-W.W.II structure

The origins of the European Major home appliance industry are rooted in a pioneering phase at the beginning of the century. The experimentation of new technical solutions was coupled with wider considerations over the social impact of the new machines (Frederick, 1913). The geographical and political fragmentation of the European markets and the marked differences in the overall wealth distribution among its countries, however, constrained the industry to a national producer structure, with a diffuse presence of U.S. manufacturers as the dominant players.

After W.W.II, U.S. manufacturers were still present in several European countries covering all the different product lines. Kelvinator's refrigerators manufacturing facilities were located in the U.K. and in Italy, Frigidaire was present in the U.K., West Germany and France and Whirlpool produced refrigerators and washers in France. The overall scale of U.S. manufacturing units, however, was considerably limited if compared with their home-based plants. While the former did not exceeded 100,000 pieces per year, with an average of 50,000, the latter reflected heavy investment in manufacturing capacity with an average of 800,000 pieces per year (Paba, 1991b).

The limited scale of their European subsidiaries preluded to a substantial pull-out of U.S. manufacturers from European markets. Two main reasons were behind this choice. First, there were doubts about the potentials for growth in the demand for durable goods. Castellano (1965) quotes a report of General Motors of Switzerland indicating a generally low refrigeration consciousness which wouldn't have sustained further investments. Second, the patterns of demand within Europe appeared not only too diversified to justify scale-investment, but also too different from the fast growing U.S. market. Technical differences reflecting asymmetries between Europe and the U.S. required a stronger effort in localized customization and made the mere transfer of product design from the home-base to the foreign subsidiaries unfeasible. U.S. manufactured products, for example, were generally too large in size for European homes, thus requiring a substantial re-engineering effort.

The fragmentation of European demand and its role in shaping the technological base of the whole industry would remain an underlying trait of the whole evolution of the Major home appliances industry in Europe and represented a valid concern for U.S. manufacturers. The lack of faith in markets growth, however, soon proved to be wrong. The direct consequences of the steadiness of established competitors generated up to the early '60s a rapid growth in the number of competitors. New entrants, as in the U.S. in the early 1900, came from industries where the technological base favored related diversification. Auto-makers such as FIAT in Italy already managed mass-production techniques and metal casting operations and were therefore facilitated in transferring their production know-how. Similarly, electric companies such as for example Philips in the Netherlands or Bosch in West Germany, found a natural expansion of their activities into the production of electrically powered devices.

The majority of the newly operating firms, however, were initiated by local entrepreneurs. In the U.K. between 1955 and 1964 16 new producers entered the washing machine sector and 15 in the refrigerator sector. In Italy, washing machine manufacturers totaled a high 50 in the late fifties. Similarly fragmented structures were also common to West Germany and France. Among the 67 major European producers operating in 1964, around 50 were of entrepreneurial origin and according to some estimates there were 130-150 other small firms with average volumes of 10,000 units per year accounting for roughly 15% of the overall market (Paba, 1991b).

Examples of entrepreneurial firms which would have then shaped the industry are common in every country. In the U.K. Wilkins and Mitchell specialized in washing machines and reached a high 12% of the national market by the '60s. In West Germany Miele quickly focused on high-end niches and established its brand as a high quality one. In Italy among the many new firms entering the industry Zanussi, Ignis, Candy and Merloni soon started to emerge as low cost/high volumes producers.

3.2.2 From local competition to national oligopolies

The high number of competitors supported by a growing demand generated intense levels of competition in all the different countries and favored greater intra-community trading. The high-cost, low volumes in small batches operating structures of most of local manufacturers were incompatible, though, with the changing patterns of international trade. In the late '50s Italian producers started to invest heavily in large scale automated plants focusing on narrow ranges of standardized products and quickly captured a substantial portion of the international markets leveraging on cost advantages.

At the beginning of the '60s, however, strong import tariffs within Europe were still sheltering local competitors and limiting selection processes within national boarders. Before the elimination of intra-European tariffs, Italy was imposing a 34% import tariff on electric products, France a 22% tariff and Germany a 8% tariff. Concentration on the producers side, therefore, occurred all around Europe at the national level and strong inter-country differences started to emerge.

A first comparison at the country level could be made along the width of the product line offered. While it is still too soon to observe clear benefits from a widespread presence on all the four main segments (refrigerators, washers and dryers, dishwashers, stoves and ovens) due to brand loyalty and stronger distribution power which will appear as critical in the 70's, European companies varied considerably in their choices (Paba, 1991a). On the one hand, British manufacturers tended to focus on specific products and invested in dedicated manufacturing capacity. On the other hand, in Germany, France and Italy the major competitors offered the whole line of products, with considerable size differences. The total 1964 annual production of the major French Major home appliances manufacturer, Thomson-Houston, was only half of the total annual production of the first West German manufacturer, Bosch, and almost a third of the first Italian manufacturer Ignis, which was the largest producer in Europe. These profound scale asymmetries are confirmed by a wider comparison encompassing the other national producers (see table 3.1).

Table 3.1 - Size differences of national producers in 1964 (thousands of units)

	France	West Germany	Italy
First producer	300	600	820
First three producers average	247	550	690
First ten producers average	178	315	375
Overall average	107	185	196

National differences also emerged with respect to market positioning choices. West Germany producers concentrated in the medium-high range, starting to establishing the base for a strong reputation for the quality and the reliability of their products. On the opposite verge, Italian manufacturers disregarded investments in market positioning and focused on cost-based strategies operating with own brands in the lower end of the spectrum. To saturate their production capacity, they also functioned as manufacturing subcontractors for several foreign producers selling under their own labels. The distinction between high vs. low end focusing was more blurred in the U.K. and in France where both strategies co-existed. This lack of focus, coupled with insufficient investments in production capacity, represented a profound weakness in the international competitive arena, which will ultimately led to a substantially limited role of U.K. firms outside their national market, and the demise of the French industry as a whole.

3.2.3 International competition

The low-cost strategy adopted by Italian firms reflected an inherent weakness of their brands. As late entrants in the market, based on entrepreneurial efforts to invest in a new and growing business they initially lacked both the resources and the expertise to promote effective brand strategies. They foresaw, however, the economic implications of technological investments in production technologies and heavily reinvested the initially high profits internally, concentrating on the rationalization and mechanization of the whole production process.

In the case of refrigerators, for example, Italians were the first to replace fiberglass insulation with rigid vacuum polystyrene liners and interstitial poliuretan foam (Owen, 1983). The substitution of fiberglass allowed major changes in the whole cabinet-making process, increasing its automation with fewer welding and the use of thinner walls and doors. New production technologies required larger scale to be exploited. According to some estimates, the minimum efficient scale for a refrigerator plant in 1965 was around 500,000 units, with an increase in the production costs of about 8% for a plant capacity of 250,000 (Pratten, 1971).[2]

[2] According to other authors, the minimum efficient scale at the plant level in the '70s was around 800,000

Regardless of a more fragmented structure of the internal competitive market, therefore, the cost advantage of Italian producers quickly translated into higher exports in all the different product segments of the industry. Figure 3.1 reports the export share of production of Italian firms by type of products between 1956 and 1975. With different lags, it shows a consistent pattern of increase in the exports from an average low 10/20 % in the late '50s early '60s, to an extremely high 60/70% for refrigerators and 50% for washers in the early '70s.

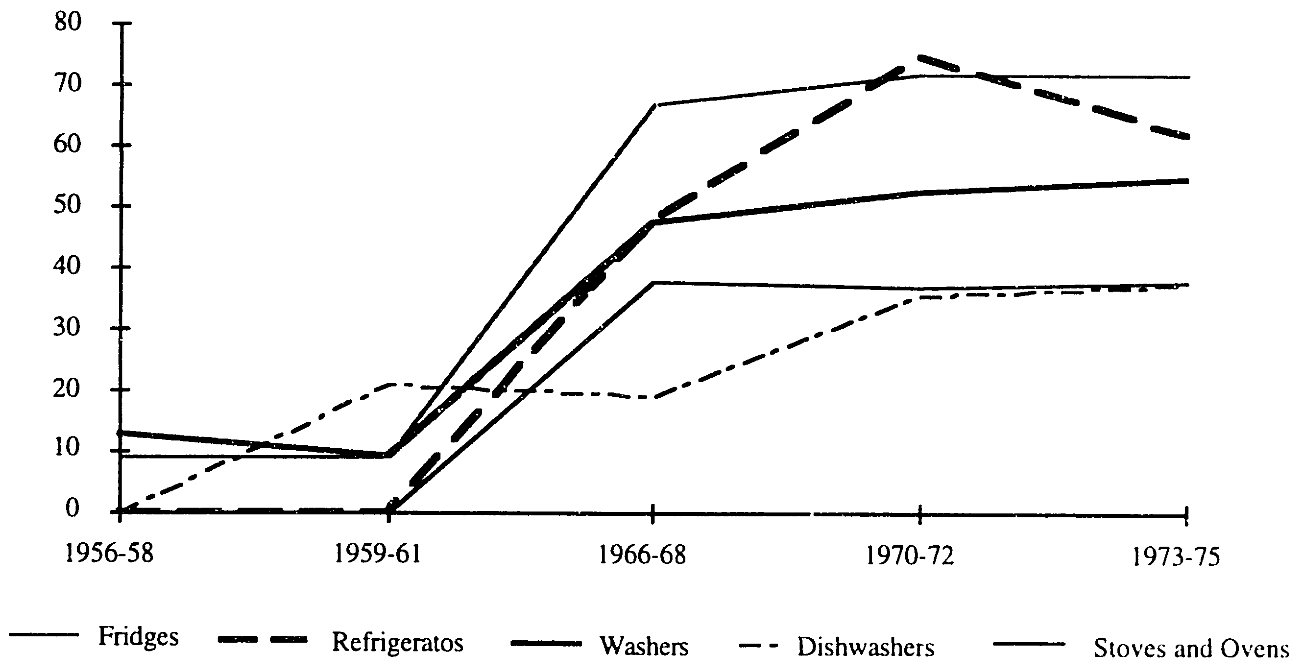

Figure 3.1 - Percentage of Italian exports over total production by product type: 1956-1975.

The growing markets of the '60s and the increased intra-community trade due to the lowering of trade barriers facilitated a widespread growth of Italian manufactured products

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units per year (Scherer, 1975; Balloni, 1978) and 1.2 ml. units per year in the early '80s (Owen, 1983).

all around Europe. By the beginning of the '70s, country level market share data indicate a dominant position of Italian manufacturers for refrigerators in all the major countries (see table 3.2). Their market share in Germany grew from 7% in 1964 to 36% in 1970. In the same period, in France it went from 15% to 47%, and in the U.K. from 5% to 24%. Similar observations are possible for washers, although in this product segment competition was still high especially in some countries, like France or the U.K., where the demand patterns and the presence of specialized producers limited the effects of lower manufacturing costs.

Table 3.2 - Italian manufacturer's market share in refrigerators and washers: 1964-1970.

	1964	1966	1968	1970
Refrigerators				
West Germany	7	18	27	36
France	15	34	41	47
U.K.	5	10	26	24
Washers				
West Germany	-	14	26	28
France	-	11	14	14
U.K.	-	3	8	8

Source: (Paba, 1991b)

The widening of markets deeply affected the internal structure of national industries. While the lack of marketing expertise and the overall positioning of Italian brands in the lower range of the markets allowed high end producers to be sheltered from the general decrease in prices triggered by economies of scale effects, inefficiencies quickly led to exits in the absence of a strong brand reputation. By 1970, only 38 of the 71 Major home appliances manufacturer operating in 1964 were still present. The concentration process occurred homogeneously in all the different nations favoring the emergence of local oligopolies formed by some internationally oriented players and some highly specialized ones, mainly focusing within national boarders. Following the Italians' lead, growth processes were the results of investments in production capacity either directly, or through the acquisition of weaker competitors. While the concentration of manufacturing capacity will become a common denominator of the subsequent evolution of the industry, at this stage it did not encompass a direct acquisition of market share. The acquired brands were in fact generally very weak and they were soon substituted by those of the acquiring partners.

By the beginning of 1970 Hotpoint was the clear dominant player in the U.K. such as in France was the Thomson-Brandt group.[3] The group was the result of the merger of Thomson-Houston and Hotchkins-Brandt and the acquisition of several smaller French manufacturers like Surmerlec and Sud Aviation backed by the Government attempting to consolidate the internal productive structure. In Italy, Ignis and Zanussi were the largest producers, challenged by several aggressive medium size firms like Candy and Merloni, while in West Germany Bosch, Siemens, AEG and Miele operated in a market much less fragmented, with clear differences in size and product offer between these four and their competitors.

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[3] Both Hotpoint and Thomson-Brandt originated from GE European branches. In 1894 GE founded in the U.K. British Thompson Houston which, in 1926, after a merger with Metropolitan Vickers, became Associated Electrical Industries (AEI) whose division, Hotpoint, focused on home-appliances. In 1954, GE exited from AEI-Hotpoint. In the early '60s GE also exited from Thompson-Houston in France.

3.2.4 Maturity and the emergence of a European oligopoly

The growth in the demand for Major home appliances which characterized all the European markets for almost 20 years after the W.W.II finally ended with the beginning of the '70s. By 1972, the saturation level of the major markets, calculated as penetration in the households, was around 80% for refrigerators and around 70% for washers (see table 3.3). Dishwashers were still offering good potentials for growth, though, due to their later introduction in the market and the peculiarities of the acquisition patterns of home-appliances (Wells and Dossabhoy, 1993). The importance of substitution vs. first purchase demand increased accordingly in all product segments. By the early '80s, on average, 9 out of ten refrigerators and 8 out of 10 washers were bought to replace older models already present in the household (see table 3.3).

Table 3.3 - Refrigerators and Washers Market saturation levels (%) by country: 1956-1984.

	1956	1964	1966	1968	1970	1972	1982	1984
Refrigerators								
Italy	2.8	48.0	62.0	74.0	83.0	90.0	94.0	97.0
France	13.1	53.0	63.0	72.9	80.2	83.0	95.0	99.0
West Germany	13.0	54.0	n.a.	80.0	n.a.	91.3	95.0	97.0
U.K.	10.7	n.a.	n.a.	59.0	n.a.	71.0	93.0	98.0
Washers								
Italy	1.3	20.0	33.0	47.0	58.0	68.0	90.0	90.0
France	14.2	40.0	44.0	50.4	56.9	60.0	80.0	84.0
West Germany	16.0	46.0	56.0	66.0	74.0	78.6	89.0	90.0
U.K.	24.6	58.0	n.a.	64.0	n.a.	67.0	79.0	80.0

Source: Marketing in Europe (various years), Pepe (1988), Paba (1991b).

The changes in the structural characteristics of demand were soon reflected in the key sources of competitive advantage. The higher consciousness and familiarity of consumers with the products increased the role of quality and reliability features over price in the purchasing process. The marked decrease in prices occurred during the '60s, in fact, could not be matched any longer. Owen's estimates (1983) indicate a decrease in real term prices between 1956 and 1970 of almost 50% for refrigerators, and of almost 60% for washers. Product innovations and investments in advertising, customers assistance structures and direct control of distribution channels to insure the proper product positioning in the consumer market, therefore, quickly became the key for success, and low-end producers started to be severely penalized.

The increasing importance of brand loyalty and reputation effects also increased the strategic value of a complete offer (Porter, 1976; Schmalensee, 1982). Buying patterns, in fact, showed that customers purchasing different home appliances tended to prefer brands they already owned not only when substituting old models, but also when purchasing different products (Paba, 1991a). Specialized producers leveraging on low production cost structures based on large manufacturing scale and weak brand positions suddenly faced a stagnant market with excess capacity and increasing brand loyalty, where the only feasible alternatives for survival were represented by product line integration (e.g. Candy (I)) or specialization on high-end segments (e.g. Scholtes (F), San Giorgio (I)).

The challenges presented by the new competitive scenario triggered profound changes in the structure of the industry. National competitors who had benefited in the past by the high level of demand and mainly operated as subcontractors for foreign manufacturers or for independent distributors were now suffering from cut-throat price competition and lacked negotiation power to reposition their offer. In addition to that, the entrepreneurial form typical of these firms which had represented a distinguished characteristic in their successful growth, seemed to be inappropriate to manage the transition (Balloni, 1978). The major national players, therefore, progressively eroded market share to the smaller players. Ultimately, a second wave of acquisitions and exits further increased the level of concentration at the national scale.

Concentration processes, however, were not limited within national borders. On the contrary, the process of international consolidation finally realized during the '80s finds its roots during the '70s. Zanussi of Italy quickly became the major European manufacturer in term of production capacity through a series of acquisitions in the internal market and an alliance with the West German Aeg-Telefunken which acquired 20% of its shares.[4] Philips of Netherlands acquired Ignis of Italy in a major operation which made the Dutch producer the second European group with a market share of about 11% in 1976. In West Germany Bosch, specialized in refrigerators, and Siemens, specialized in washers, merged in 1972 forming the fourth European group which in 1976 accounted for roughly 8% of total production and covered the whole product range. Aeg-Telefunken completed its restructuring efforts through the acquisition of Zanker in 1971 and the home-appliance division of BBC of Switzerland in 1973. By 1976 it was the 6th European producer accounting for 6.1% of total volumes. The fifth producer in 1976 was Thomson-Brandt of France with 7.6% of total volumes. After the exit from the market of Frigidaire and Vendome and the acquisition of Arthur Martin by Electrolux in 1976, the Thomson-Brandt group remained the only large integrated French producer in the European market.

[4] The alliance will be ultimately terminated in 1979 when Zanussi bought back its shares.

Table 3.4 - Concentration indexes of the European White Goods Industry: 1964-1984.

Index	1964	1970	1976	1984
Herfindhal-Hirschman	0.0276	0.0583	0.0689	0.1025
First producer share	7.30	15.29	16.01	21.38
First 3 producers share	18.65	34.08	35.18	47.63
First 10 producers share	45.14	61.57	70.89	82.14

Source: Paba, 1991b.

At the beginning of the '80s the European Major home appliances industry was therefore characterized by its highest level of concentration, with the first three producers accounting for roughly 35% of the market and the first ten for roughly 48% of the market (see table 3.4). Despite the sensible changes with respect to the past, however, the industry still suffered from excess capacity and its concentration levels were far below the U.S. ones, where the first three producers accounted for 85% of the market. While growth by internal investments was clearly not an option anymore, the structural inefficiencies of several players offered further opportunities for growth by acquisitions.

Electrolux history is exemplary in this sense. Through a series of aggressive acquisitions of troubled competitors in Europe and in the U.S., the Swedish conglomerate became the second largest Major home appliances manufacturer in the world and the first in Europe with a 23% market share in 1988. Similarly, Philips acquired several small producers and, in 1982 and 1983 the West German producers Lepper and Bauknecht becoming the second largest European manufacturer by 1988. Aggressive moves were also made by three Italian firms, Merloni, Candy and, more recently, Ocean. Merloni started at the end of the '70s to invest directly in manufacturing operations in Portugal and with targeted acquisitions in the U.K.. In 1988 it then acquired Indesit (I), the third European producer in 1976, and Scholtes (F), strengthening its position in the medium-low range and opening a window in the high range. Candy also moved both within and outside the national borders and by 1988 controlled 7% of the European market. Finally, Ocean, an Italian producer specialized in refrigerators, first merged with San Giorgio (I), which was focused in the washing segments. In 1992 it then bought Thomson-Brandt in an operation which finally marked the demise of the French industry, becoming the fifth European producer.

The '80s were also the years during which U.S. manufacturer re-entered the European market in a move which, coupled with the Electrolux acquisition of the American White Consolidated Industries, marks a concentration of the Major home appliances manufacturers at the global scale. In 1988 Philips and Whirlpool formed a joint venture which ultimately dissolved in 1991 with the acquisition of Philips home-appliance division by Whirlpool, making the U.S. manufacturer the largest in the world. In 1985 the U.S. company Chicago Pacific acquired the British Hoover, leader in the washing sector, and was further acquired in 1989 by Maytag, and sold in 1995 to Candy. After the acquisition, the group Maytag-Hoover became the 5th world producer.

At the beginning of the 90's, the competitive structure of the industry therefore sees a well identified set of European producers (Electrolux-Zanussi, Bosch-Siemens, Merloni, Ocean-Thompson, Candy) which have survived through the different evolutionary stages and have now reached a substantially critical mass. They have been re-joined in the competitive arena by U.S. manufacturers (Whirlpool, Maytag, GE) who initially dominated the market and pulled out just after W.W.II considering not promising the growth opportunities of the European markets, and have re-entered through targeted acquisition of troubled large manufacturers such as Philips and Hoover who were not able to make the final transition.

3.3 The role of technological innovation

Product innovations in the Major home appliances evolved around dedicated mechanical solutions and more recently were impacted by the introduction of electronics. Process innovations showed high level of technological inter relatedness and benefited from cross-industry transfers (Rosenberg, 1982). Advancements in the technical characteristics of the products have therefore been less visible to the end-users who have mainly experienced improvements in the satisfaction of a well defined set of needs. Moreover, product innovations have traditionally been strongly coupled with changes in process technologies.

Aside from any specific case and considering the idiosyncrasies of each different product, however, the technological evolution in the industry up until the '80s could be modeled using established frameworks (Utterback and Abernathy, 1975; Dosi, 1982; Tushman and Anderson, 1986). Product innovation stimulated by new entrepreneurial firms preceded process innovations which became dominant with the increasing role of economies of scale and price competition. The appropriability regimes of process innovation remained weak and different alternatives were experimented by the established competitors. Late movers, however, soon lacked the financial resources and the managerial capabilities to restructure their activities and suffered from market saturation. The subsequent concentration process first at the national scale and then at the international scale further triggered systemic changes aimed at better coordinating product and process changes.

Innovations in refrigerators are a good case in point. Already in the '50s, the basic features and technical characteristics had been established for a while. Metal frames were used to support the inner cabin insulated from the outside by fiberglass sheets and containing the heavy compressors used for the refrigeration process. A large size and generally bulky look were the consequences of the size of compressors and the use of fiberglass as insulating material. The first product innovation which deeply affected the product was originally introduced in the U.S. and adopted in the late '50s first by Italian manufacturers. Polystyrene liners were put between the external frame and the inner cell instead of fiberglass, and a polyurethane foam was used to complete the insulation and insure a perfect adhesion among the two. By using dedicated cooking cells to complete the polymerization and further cooling down the assembled product, insulation levels were improved and the overall product size was sensibly reduced. The external frame, in fact, was not supporting the whole refrigerators and thinner panels using fewer welds allowed for smaller units.

The impact of the new technology was increased by simultaneous changes in manufacturing techniques. Polystyrene was already used by U.S. plants where polymerization occurred in the final phases of the assembly line and represented a bottle-neck for the whole process. The phase required around 8 minutes for each product and intermediate warehouses were used to feed the polymerization cells. In addition to slowing down the whole process because of the differences in the manufacturing cycle times of the different phases, this solution generated higher direct costs related to the large number of labor intensive operations (ex. loading and unloading the molds, changing the molds for different products etc.). The inconvenient was first solved by Ignis in the early '60s by placing the cooking cells on a revolving carousel. Each assembled product was placed in a cell and the foam inserted. The speed of the carousel reflected the polymerization time and allowed for continuous loading, polymerization and unloading, speeding up the whole process.

Paba (1991b) presents a detailed example for refrigerators manufacturing of the coexistence of alternative choices in process technologies and the organization of the work flows (see figure 3.2). In one case, there was a clear separation among the different phases and production was highly standardized following a Fordist model of line automation. A u-shaped frame was casted and assembled with a back and a top panel, painted and assembled to the inner cell, which was coming from a separate line, then moved to the polymerization phase. External panels and doors were finally added. This method benefited from high economies of scale in each phase but was very rigid.

In a second type of manufacturing process, the external frame was built by using separate panels, thus reducing the complexity of the casting phases and increasing the overall flexibility. Changes could have been arranged by working on the initial cutting and shaping phases where more general purpose equipment were used, making re-tooling easier and faster. An additional phase was required before the insulation one to pre-assemble the external frame. Finally, in the third alternative, pre-painted plastic panels substituted metal ones, eliminating altogether casting and painting phases. In a pre-assembly stage the sides, the bottom and the top panels were put togetner and the refrigeration cell inserted in the frame for the subsequent foaming and polymerization. Flexibility was further increased and smaller batches became economically feasible.

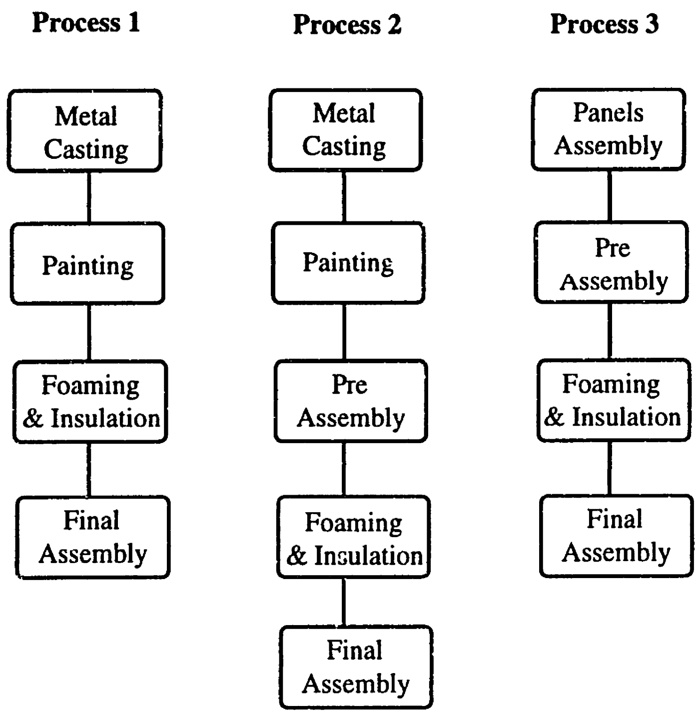

Figure 3.2 - Three different refrigerators manufacturing processes in the '70s.

The emphasis on flexibility of the third manufacturing process anticipated the next technological challenge faced by the industry. Up to the '70s, in fact, innovation occurred through an interplay of market opportunities and the availability of technical solutions. As much as product innovations in the '50s and in the '60s were favored by a growing demand, cost-reducing innovations in the '70s were the direct consequences of the increased role of internal efficiency in shaping the competitive structure of the industry. Despite its profound changes on the producers side, however, the industry remained substantially stable on the demand side. Preferences in regional markets[5] are still marked.

[5] Regiona market usually overlap with national ones, with the exception of Northern Germany, Belgium, Denmark and the Netherlands which show homogeneity of demand patterns.

Differences in washing[6] and eating habits,[7] climate,[8] house-hold characteristics and demographics are reflected in persistent heterogeneity among markets and groups of consumers.

The role and direction of technological change, therefore, ceases to be clearly identified in the product or in the process domain. Rather, the interplay between the two becomes the critical path to be explored to leverage on technology and impacts profoundly the internal organizational structure. While a focus on products or processes previously identified the organizational locus of innovation, their interrelatedness challenges existing solutions. The goal is therefore to design organizational structures able to promote the systemic changes required by the contrasting evolutionary patterns of offer and demand.

The producers' response over the years has been a switch from mass production to exploit economies of scale in manufacturing, to flexible automation to promote quick product turn-over and shorter life-cycles. Table 3.5 reports the number of brands, models and models per brand in the UK washing machine market between 1976 and 1987. It shows that within ten years the number of models per brand increased from 2.4 to 5.6, despite an increase in the number of brands from 22 to 36.

In a recent study on the computer industry Pine (1993) used the term *mass-customization* to identify these seemingly contrasting evolutionary patterns of offer and demand. On the one hand, the structure of the offer is shaped by the increasing role of technological intensity. On the other hand, demand becomes more sophisticated and

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[6] Southern countries tend to prefer lower spin-speed and to use cold rather than hot water cycles. Northern countries are more environmental conscious and sensible to energy and detergent savings (Pepe, 1988; Baden-Fuller and Stopford, 1991).

[7] Frozen foods market penetration, although increasing, is still quite low in southern countries like Italy or Spain were consumers tend to prefer fresh foods (EIU, 1986).

[8] Market penetration of dryers and washer-dryers in southern Europe tend to still be fairly limited. In Italy, for example, recent estimate indicate values around 5% (EIU, 1994).

heterogeneous, or like in the European Major home appliances industry maintains these characteristics typical of initial stages. To successfully face this environment, producers need to switch from scale to flexibility on the manufacturing side and to invest accordingly in product development activities.[9] Small batches and shorter life-cycles represent the boundaries of development activities which have to privilege product families with a long-lasting technological core to be *"re-freshed"* periodically through subsequent minor changes. Self-cannibalization of products becomes not only theoretically justified, but operationally optimal to saturate manufacturing capabilities.

Table 3.5 - Brands and models in the U.K. washing machine market: 1976-1987.

Year	Brands	Models	Models per Brand
1976	22	52	2.4
1977	23	67	2.9
1978	23	68	3.0
1979	25	73	2.9
1980	28	77	2.8
1981	34	107	3.2
1982	34	121	3.6
1983	38	140	3.7
1984	37	152	4.1
1985	35	171	4.9
1986	37	189	5.1
1987	36	201	5.6

Source: U.K. Consumers' Association Reports (reported in Baden-Fuller and Stopford (1991)).

[9] In 1990 and in 1992 Electrolux-Zanussi opened two new manufacturing facilities for the making of refrigerators (Susegana) and washers (Porcìa), with an estimated investment of 100 ml. US$ and 180 ml. US$, and a capacity of more than 1 ml. and 1.6 ml pieces per year respectively. CIM technologies are at the heart of both plants where faster re-tooling decreased the economic-size of batches. In the Porcia plant, for example, all the different 700 models currently offered can be produced (Bongiovanni, 1992).

3.4 The changes of organizational structures

The structural evolution of the industry and the changes in the sources of competitive advantage are reflected to a great extent in the evolution of the organizational forms adopted by Major home appliances manufacturers. After the determinant role of entrepreneurial new entrants filling the gap generated by the contemporaneous market growth and the exit of the major U.S. multinationals, the increasing importance of scale efficiencies and the following national concentration of producers initiated a series of profound organizational changes. Internationally oriented groups started to emerge leveraging on a strong home-based position. Divisionalized forms able to cope with a widened product line and to face inter-country differences in marketing operations were quickly adopted by all major competitors.

In general, however, all major groups were strongly localized during the '70s. Integrated producers tapping more aggressively international markets were still relying on highly centralized staffs located in the original home-base where, frequently, also manufacturing activities continued to be concentrated due to the relatively low transportation costs. Such strongly localized structure was even more evident in the case of niche producers, which were also characterized by a naturally lower level of functional articulation.

An exception to these patterns was Electrolux. Characterized by a traditionally weak position in the European markets because of a limited internal market which did not foster investment in manufacturing, the Swedish group started to grow through a series of strategic acquisitions during the '70s. This strategy ultimately led to the acquisition of

Zanussi in Europe and of White Consolidated Industries in the U.S. making Electrolux the second world producer of home-appliances. Within this success story apparently simple in its main elements lay several interesting elements for a deeper analysis of the organizational implications of the evolution of the industry.

By 1984, the first three producers accounted for 48% of the European market, while in 1970 they accounted for 34% of the market and in 1964 for only 19% of the market. The increased concentration, however, did not occur through aggressive internal investments. On the contrary, firms gained market share by directly buying weaker competitors. This process of growth is typical of mature oligopolies where sunk costs represent significant barriers to exit even for highly inefficient firms. While short term fluctuations are possible, in fact, long term stability of market share distribution is characteristic of this type of industry structure, making market share the main tradable asset. The acquisition process of Philips by Whirlpool through a creation of a Joint Venture subsequently bought out by the U.S. partner is a recent example. The pattern, however, is common to all the major competitors still operating in the industry. Table 3.6 reports data on the changes in market share of the first ten companies in 1990 over the last two decades distinguishing between internal and external growth and shows the absolute relevance of this mode of growth.

The organizational consequences of the growth through external acquisitions are reflected in major restructuring actions. On the one hand, the excess of manufacturing capacity requires post acquisition rationalization of production activities. On the other hand, similar actions are more difficult with respect to brands. The main motivation of external growth, in fact, is the acquisition of such assets. The consequent proliferation of brands is common to all groups and indirectly reflects the impact of a localized and fragmented demand on the internal organization of the multi-national. Group-level brands co-exist with national ones and marketing activities are in between a centralized organizational model more typical of globalized businesses and the geographically localized ones, typical of traditional multi-national structures. Macro-organizational structures therefore present high levels of integration of technical functions (R&D, Product and Process Development units, Manufacturing) usually grouped by product lines (e.g. washers, refrigerators, cookers), and a more dispersed marketing structure, with central units responsible for brand strategies and local units in charge of specific geographic areas. Such structures might also be strongly geographically localized (i.e. Merloni) or more widespread around Europe (i.e. Electrolux).

Table 3.6 - Sources of growth of the major European White-Goods producers: 1970-1988.

	1970	1976		1988	
	mkt. share	mkt. share	Δ ext.[a]	mkt. share	Δ ext.[a]
Electrolux	1.78	2.29	0.87	22.73	18.84
Philips-Whirlpool	0.59	10.72	9.49	13.18	2.46
Bosch-Siemens	5.33	8.20	1.83	12.27	0.00
Merloni	2.37	2.24	0.00	11.36	9.12
Candy	3.73	3.85	0.12	6.36	1.44

Source: Estimates based on Paba (1991b).

[a] Estimated growth in market share through external acquisition.

The implementation of these organizational structures represent a major challenge. Competitive analysis shows not only the importance of internal efficiency in the new scenario, but also the role of flexibility, to reach a widespread market presence, and creativity, to quickly and constantly rejuvenate the offer. Internal and external coordination mechanisms are therefore the central elements to be leveraged (Goshal and Haspeslagh, 1990). In particular, product development activities become the institutional environment for the experimentation and the implementation of such coordination mechanisms, which have to be necessarily cross-functional both vertically and horizontally.

On the one hand, in fact, product and process development need to be pursued jointly to form the technical base of a diversified offer with life-cycles shifted to the family level and series of product substitutions anticipated to direct manufacturing investments. New products not only need to be modular in concept, but also their modules needs to be considered as potential sources for further innovation. Architectural changes (Henderson and Clark, 1990), therefore, become the natural evolutionary trajectory.

On the other hand, such technical considerations need to be directed by strong market feedback reflecting marked geographical differences. Such variations become a source of ideas and stimuli and at the same time indicate the necessary boundaries of the developmental activity. Contrary to traditional models of multinationals (Stopford and Wells, 1972; Hennart, 1982), though, inter-unit contacts cannot be identified unequivocally as hierarchically determined. Rather the changing nature and interdependence of the tasks requires structuring investments in coordination mechanisms such as inter-country/inter-functional personnel rotation, specific groups devoted to foster internal knowledge and the like (Goshal and Westney, 1993). Structural flexibility promoting internal learning processes is therefore the result of process rather than structure design to tackle the increased level of internal and external interdependency.

3.5 Discussion

Four distinct phases can be identified in the evolution of European Major home appliance industry (figure 3.3). A European base of producers emerged in all the major countries after W.W.II In the *entrepreneurial* phase, favored by a growing demand , significant inter-country trade barriers and the pull-out of U.S. companies. Small and medium sized firms, usually focused on specific products entered in a schumpeterian fashion, but were subsequently threatened during the *national concentration* phase, when scale effects became more and more relevant. Decreasing growth rates on the demand side and an increasing importance of market segmentation determined the gradual exit from the industry of many competitors. In the *internationalization* phase, scale-based effects propagated among countries. National competitors not able to either integrate the product offer, or occupy profitable niches, were challenged by increased levels of market saturation and lower trade barriers, with further exits from the industry in all the countries. Finally, the *international concentration* phase during the '80s offered the opportunity to established competitors to pursue aggressive acquisitions strategies to control brands and local markets, and rationalize an oversized installed manufacturing capacity.

The analysis highlighted two interesting elements. First, the industry at the inter-country level evolved according to dynamic models usually observed at the country (Carroll and Swaminathan, 1992), or at the regional level (Baum and Mezias, 1992). Inter-temporal differences characterized the emergence of evolutionary patterns first at a national level and then at an international level with changes in the structural characteristics of the environment (e.g. lower trade barriers) showing interdependencies with the organization of economic activities. Moreover, the process seemed to favor first local optimization and subsequently general optimization, suggesting to investigate evolutionary processes not only over time, but also over space and to focus on the importance of enlargements or restrictions in the competitive space.

Second, the role of technological innovation in addressing organizational choices confirmed the cyclical interactions between product and process innovation. Yet, it also provided additional evidence for the need for better frameworks to encompass the management of innovation processes facing at the same time the constraints of large scale manufacturing, and the opportunities of creative product differentiation. Regardless of its functional source, whether on the demand or on the technology side, mature mass-markets seem to converge consistently towards highly fragmented and temporarily unstable patterns of consumption. Contingency approaches to environment characteristics are therefore challenged by the interdependence of previously orthogonal dimensions and the view of innovation necessarily becomes systemic. Product, processes or components innovation cannot be considered as isolated sources of competitive advantage to be leveraged on the market. On the contrary, the development of innovation requires a systemic view of the whole process, where the combination of all elements is used strategically to set the conditions for development paths. Products are not developed anymore in isolation from their previous and future generations, but must provide the technical opportunities to develop several generations based on a common platform. Moreover, such platform has to become the basis for the commercial differentiation required by the integration of multiple brands. Modular design and development become practical ways to cope with multiple commercial targets.

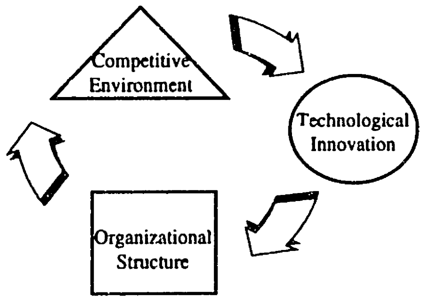
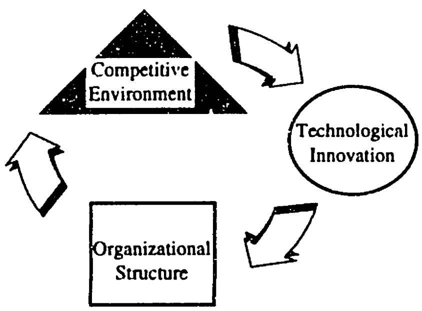
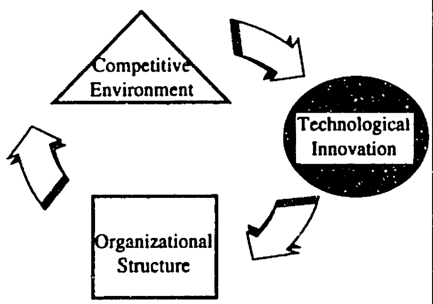
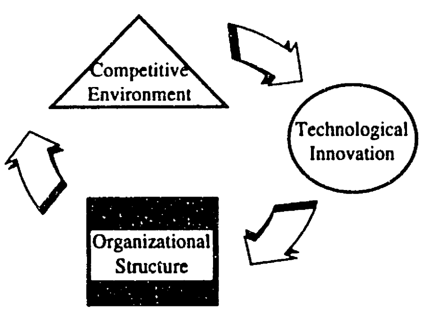
Phase	Main characteristics	Type and purpose of inter-organizational relations
Entrepreneurial Phase 	• National markets • Many competitors • Growing demand • Product innovation • Entrepreneurial firms	• Vertical *Generic supply*
National Concentration Phase 	• National markets • Fewer competitors • Demand segmentation • Component innovation • Functional structures	• Vertical *Generic Supply* • Horizontal *Product Integration*
Internationalization Phase 	• International markets • Specialized vs. Integrated competitors • Subsitution demand • Process innovation • National divisionalized structures	• Vertical *Generic/Specialized Supply* • Horizontal *Market/Volume Expansion*
International Concentration Phase 	• European market • Integrated competitors • Brand loyalty • Systemic innovation • International divisionalization	• Vertical *Innovative Supply* • Horizontal *Brand Integration*

Figure 3.3 - Evolutionary phases and inter-organizational relations in the industry

The response of European Major home appliances manufacturers to these challenges has been a constant shaping of internal structures around the technological base required to achieve competitive advantage. Failures along these strategies resulted in exits at different times. Structures cease to be focus of organizational design in favor of processes. The contemporary need for size and scope is not achieved merely by functional or geographical separation, but is rather fostered through increased inter-unit coordination. Electrolux for example, has organized its Major home appliances business around three product divisions (the "wet", the "cold" and the "hot" divisions) which are responsible for the whole development process and for the subsequent manufacturing, and have to coordinate with separate marketing units organized geographically and responsible for the distribution, advertisement and post-sales assistance, which respond to the central strategic marketing unit. Specific activities, such as product development, where all the different and frequently contradictory task characteristics are conveyed, become the institutional environment to shape the internal structure of the organization and to adapt it to the changed nature of the external environment.

Similar efforts in the coordination and integration of internal resources are also emerging when we analyze inter-organizational relations. While horizontal relationships emerged more as anticipatory moves of subsequent mergers or acquisitions (Nanda and Williamson, 1994), vertical relationships became overtime an important characteristic of the successful players. Suppliers relationships were initially limited to short term purchase contracts, with size differences between manufacturers and suppliers heavily used as bargaining leverage. Influenced by the changes in the manufacturer side, however, during the years the different supplier industries (like for example mold producers, plastic producers, or more recent electronic component manufacturers) became more and more valuable sources of specific knowledge and competencies, turning the management of external relations into a fundamental source of competitive advantage. For example, Merloni factory integration systems linking the plants with its suppliers is widely recognized in the industry as an effective lean response to the challenges of its limited size and low price premium brands. In all major groups, purchasing policies have been directed to a rationalization of the suppliers base, with specific programs directed to their integration at different stages both in the manufacturing and in the development process.

Theis evolution in the establishment and management of inter-organizational relations in the industry offers some specific advantages for a study of inter-organizational relationships in the development of innovation. First, the changing perspective on the role of suppliers in innovative processes also corresponds to the actual presence of articulated interactions. Second, together with more evolved cases of collaboration, the articulation of the supplier base still retain a varied set of cases. High variance in the types and characteristics of the inter-organizational relations observed is therefore present within the same industrial setting. Third, because of the systemic nature of the products and their technical architecture the manufacturers are becoming more and more expert integrators who need to combine somebody else's specialized knowledge. Fourth, the limited margins on the product and the high impact of outside developed (and sometimes also manufactured) parts make inter-organizational relations in new product development a key area of managerial attention. For these reasons I decided to examine supplier-manufacturer interactions in new product development projects in this industry to study the relationships between task characteristics, contractual and procedural coordination, and performance. The next chapter presents this study.

CHAPTER 4
The trade-off between efficiency and learning in inter-organizational relations

4.1 Introduction

Research on innovation development processes has found evidence in different settings for the importance of combining complementary competencies to achieve desired goals (Allen, 1977; Larson and Gobeli, 1988; Cohen and Levinthal, 1990; Ancona and Caldwell, 1992). Actors' cognitive limitations coupled with increasing levels of knowledge attrition and specialization have increased in several fields the importance of knowledge combination and extended it from the intra-organizational to the inter-organizational domain (Clark, 1989; Link and Tassey, 1989 ; Pisano, 1990; Arora and Gambardella, 1991).

Despite these theoretical assessments, however, the empirical evidence of the beneficial outcomes deriving from activating inter-organizational relationships is still very limited and controversial (Mitchell and Singh, 1996). The meta-analysis presented in chapter 2 provided cumulative evidence for the absence of clear theoretical and empirical answers to these issue. Moreover, it pointed to two major research design problems related to these findings: (1) an incomplete articulation of the coordination mechanisms used to set up and implement the relationship, and (2) the rare inclusion of outcome measures in the analysis.

What kind of impact do such relationships have on the partners involved and which processes account for these effects remain two major research questions in studying inter-organizational relationships in the development of innovation. In this chapter, I present an empirical study designed to address these research questions and test the multi-dimensional framework introduced in chapter 2, linking the characteristics of the task being partitioned, the structuring alternatives employed to govern the relationship, and the relationship outcome.

Section 4.2 elaborates the theoretical arguments linking relationship type, structuring alternatives and outcome. First, I review the theoretical motivations for the activation of inter-organizational outcomes distinguishing between efficiency-oriented and learning-oriented ties. Efficiency-seeking ties are aimed at reducing the overall costs associated with the transaction. Learning-oriented ties are established to widen the partners' resource base. Then, building on evolutionary approaches to economic activities, I frame inter-organizational relationships in the development of innovations as joint search processes. Such processes require efforts from all the agents involved in different individual tasks, all necessary to achieve the final aggregate goal. Distinguishing between the level of interdependency among the tasks and the scope of the knowledge involved, coordination efforts are related to efficiency-oriented ties and learning-oriented ones. A set of hypotheses is developed to test the marginal success of certain types of relationships in achieving different outcomes.

Section 4.3 presents the empirical study based on 50 manufacturer-supplier relationships in three projects developed between 1992 and 1995 in the European major home appliance industry. The use of a single dyadic interaction between the manufacturer and one supplier as the unit of analysis is discussed and linked to the research design, the variables, and the methods used for the data analysis. Section 4.4 presents the results of the study showing strong support for the role of relational characteristics in understanding relational outcome. More specifically, seven of the eight hypotheses developed in section 4.2 find support in the analysis of the data leading to the conclusion that (a) the type of knowledge being partitioned and the level of task-interdependency are important predictors of the outcome of the relationship, and (b) a clear trade-off exists between efficiency-oriented and learning-oriented ties.

These results are elaborated further in section 4.5, where they are discussed by comparing the contractual and procedural coordination mechanisms used within the different types of relationships. While the sample examined showed invariance in the set of contractual coordination mechanisms used, procedural coordination mechanisms emerged as a significant mediating dimension between task characteristics and relationship outcome. Efficiency-oriented types require fewer coordination efforts. They are initiated later in the project, communication is less frequent and it occurs through non-dedicated channels. Problem solving is generally sequential rather than overlapping. In contrast, in learning-oriented relationships suppliers are contacted well ahead of the project and start to work in overlap with the manufacturer, therefore generating higher levels of communication, frequently through dedicated channels. Section 4.6 concludes highlighting the implications of these findings for the assessment of the theoretical framework developed in chapter 2 and linking them to the following chapters.

4.2 Inter-organizational outcome and the nature of joint problem solving activities

4.2.1 Differences in inter-organizational outcome

According to several strands of literature, inter-organizational relations can be activated with two objectives in mind: (a) increase the overall efficiency of the process , or (b) tap into external resources, otherwise inaccessible, to augment the internal assets base, even at the expense of short term inefficiencies. The two positions are somehow different not only in their vision of the expected outcomes, but also in the characterization of the processes driving such outcomes.

Efficiency increasing arguments consider that economic activities could indifferently be organized through internal integration or through the combination and coordination of the work of separate economic agents (Alchian and Demsetz, 1972; Williamson, 1975; Milgrom and Roberts, 1992). The choice among the alternatives is mainly cost driven and the cost function can be built considering the peculiar characteristics of the transaction itself and those of the actors involved (Williamson, 1979; Joskow, 1987), or rather incorporate the single cost functions of the actors involved and compare the resulting outcome to the internal integration solution (Brusco, 1982; Piore and Sabel, 1984). The Transaction Cost Economic tradition builds on the first notion of cost efficiency to show how, under certain environmental condition (low uncertainty), investments in generic assets can be sub-contracted out to increase the overall performance of the system, reducing the total cost function by economizing on transaction related costs (Williamson, 1989). Similarly, the flexible specialization model describes the division of labor realized not under the roof of a multiple unit company, but rather through the interaction of several specialized, distinct firms (Piore and Sabel, 1984; Best, 1990). By leveraging on system-level economies, a non-integrated structure can adapt more quickly to changes in the markets, relying on higher levels of specialization to achieve a less costly and quicker response to increasing levels of demand. Furthermore, the effects of exogenous shocks in demand are spread across multiple units, thus decreasing the risks for the whole system.

In both cases, however, the main underlying assumption is that the assets being transacted are perfectly transferable and available to the interested agents. If the integration decision prevails, therefore, there are no obstacles to the substitution of external activities via internal investments. This notion of perfect tradability, however, is rather controversial (Barney, 1991) and markets have repetitively been proven to fail as viable structures to gain access to and transfer certain types of assets (Mariotti and Cainarca, 1986; Kogut, 1988; Pisano, 1991). Conversely, inter-organizational relations arrangements have started to be considered not only as efficiency increasing solutions, but also as the preferred channels to transfer certain types of assets (Roberts and Berry, 1985; Contractor and Lorange, 1988; Doz et al., 1989; Lorenzoni and Baden-Fuller, 1995).

Since Arrow's famous information paradox (1974), there has been an effort to distinguish among different assets according to whether or not they could easily be transferred through market transactions. Building on the work of Polanyi (1967), several authors have proposed a knowledge base interpretation of non-tradability (Teece, 1986; Winter, 1987; von Hippel, 1988; Nonaka, 1994), distinguishing between explicit and tacit knowledge. Whenever the knowledge is explicit, it can easily be codified and therefore transferred among different actors. On the contrary, whenever the knowledge is tacit, it's "sticky" to whomever owns that knowledge (von Hippel, 1994).

This "stickiness", a label for the degree of "non tradability", depends on cognitive limitations of the agents involved (March and Simon, 1958; Cyert and March, 1963) and on the embeddedness of knowledge assets within a particular setting (Barney, 1991). On the one hand, the recipient's or the knowledge holder's bounded rationality can account for his or her inability to codify the relevant knowledge and make it explicit (and therefore perfectly tradable). On the other hand, the development context itself becomes necessary to fully understand the consequences and implications of the knowledge being traded (Tyre and von Hippel, 1993). In the first case, the separation of the critical asset from the owner is simply not feasible, almost making the knowledge owner become the asset. In the second case, the separation of the asset from its incubating environment sensibly affects its value for the recipient. Inter-organizational arrangements become a way to overcome the difficulties of trading knowledge base assets, by providing the opportunities to establish direct contacts with the sources of knowledge and their development environments (Badaracco, 1991; Ciborra, 1991).

To fully understand the outcome implications of inter-organizational relationships, we therefore need to focus on the characteristics of the work being partitioned among the different actors. Both efficiency and learning oriented ties are reasonable to establish. Yet, different goals will require different types of structuring investments in the relationship. Internal development costs can be reduced by sub-contracting to outside agents part of the associated work. However, the characteristics of the work being partitioned will influence the achievement of this goal and need to be considered carefully to structure the relationship appropriately. In the next section I link the characteristics of the work being partitioned and the expected outcome, considering the role of structuring alternatives.

4.2.2 Dimensions of joint problem solving activities: knowledge scope and level of task interdependencies

Innovation processes involve the search for new solutions to meet market opportunities through technological and organizational efforts. In any search process, the actors involved face a problem and have to fulfill different tasks: first, define the problem itself; second, decide on how to approach the identification and selection of the solution to the problem; third, define the final solution in detail. Actors engage in what Nelson and Winter have called "heuristic search processes" (1977, p. 52), which affect their evolutionary patterns of development. Analysis of the characteristics of the knowledge underlying search processes therefore becomes a fundamental starting point in understanding these patterns and their implications for the actors involved.

Building on previous works on the theory of design (Marple, 1961; Alexander, 1964), Clark (1985) proposed to look at search processes as problem solving activities by focusing on the level at which the search process occurs. Problem solving efforts can be devoted to general understanding of alternative design concepts for approaching the problem, and to the selection of one of these concepts. Subsequently, problem solvers must shift their attention to clearly define the functional parameters of the selected design concept.

Examples from several industries help to distinguish between these two levels of activities. The choice between an electric or an internal combustion engine in the automotive industry, between chemical synthesis processes vs. rational drug design in the pharmaceutical industry, or the choice of an open-system architecture in the computer industry represent selections among different design concepts which narrow the solution space. Yet, in each case, many elements still need to be determined. For example, for car engines one has to determine the targeted power, fuel consumption levels, physical positioning in the car-body and the like. Definition of the targeted level of fuel consumption and power have then to be matched with choices about the number of cylinders, of valves per cylinder, of how the valves are activated, and so on.

The distinction between design concept and functional parameter choice move these operational differences to analytical levels. The identified scope of the knowledge search is thus central in understanding the patterns of development of the search itself. On the one hand, selection of the design concept impacts the search process in the functional domain by narrowing it down. On the other hand, focus upon the functional parameter domain might limit the opportunities offered by the choice of an alternative design concept (March, 1981).

Scholars of organizations have approached these issues in a similar vein, modeling organizations as information processing systems performing joint actions for the achievement of a common goal (Thompson, 1967; Duncan, 1972; Galbraith, 1974; Nadler and Tushman, 1988). Joint action is necessary because of the bounded rationality of the actors and the characteristics of the tasks to be performed (Cyert and March, 1963). Individual actors need to access complementary resources and exchange information and products to be able to complete their individual tasks. The nature of the task affects these information flows. Depending on the level of uncertainty in the task domain, actors will have to engage in more or less extensive and complex search processes (Burns and Stalker, 1961; Woodward, 1965). Albeit slightly differently formulated and operationalized (Thompson, 1967), the level of task uncertainty can be framed similar to the approach proposed by Clark (1985).On the one hand, the ultimate goal might be clear and identified, but the means to achieve it need to be specified. On the other hand, the goal itself might need to be determined. In the first case, the actors involved know the structure of the problem as well as the relevant variables, and focus on the definition of the values to be assigned to these variables. In the second case, instead, the basic problem solving space is still unknown, either because the integration between the individual variables and the approach chosen is not clear, or because the approach itself is to be selected.

Inter-organizational relationships can be distinguished on the basis of their knowledge scope. Using Alexander's (1964) concepts, we observe relationships focused on functional parameters definition when external contacts are established to further define an already internally identified solution. Alliances for drug development and commercialization between specialized R&D organizations and larger pharmaceutical conglomerates are examples of such cases. The new chemical entity has already been identified in its molecular structure, the targeted receptors and its effects have been tested in animals. Human testing to establish proper dosage, how to administer the cure and possible side effects, however, have yet to be determined and the partnership is established for this purpose.

On the contrary, we observe relationships focused on design concepts selection whenever the external links are specifically used to identify the concept domain and select among possible higher level alternatives. Continuing to focus on drug discovery processes, this is the goal of alliances between pharmaceutical firms and biotechnology firms. The pathology to be cured is identified, but how to identify a potential set of new compounds and what chemical structure should characterize such compounds is still unclear.

The amount and type of information to be exchanged between the partners involved in the relationship differs depending on the level of knowledge scope, and so are the processes through which this information is exchanged. In the first case, all the relevant information is readily available among the partners and is easy to transfer. Any knowledge involved in the transaction is explicit, and likely to be codified in some form. Conversely, any information being transferred among the parties can flow through predetermined channels and the coordination efforts required are limited. In the second case, on the contrary, the knowledge being transferred is less codifiable and wider in scope. Higher investments in the information transfer process are required from the parties to coordinate the transaction. Iterative processes to identify a solution are initiated and complex interactions required to finally make a choice. This leads to the following hypothesis, linking knowledge scope and relationship outcome:

H1: The lower the knowledge scope of the relationship, the greater the efficiency of the relationship.

While an up front definition of the problem solving domain by one of the actors decreases the corresponding coordination investments, it also limits the opportunities for widening the partners knowledge base. Close interactions establish the conditions to reconsider the internal set of routines which determine and characterize the existing knowledge base. The type of information transferred and how is transferred represent the necessary bases for learning processes to occur (Huber, 1991; Nonaka, 1994). Numerous studies on problem solving activities showed how non-codifiable knowledge can effectively be transacted by person to person direct communication (Imai et al., 1985; Clark and Fujimoto, 1991; Aoshima, 1996), physical co-location (Allen, 1977; Tyre and von Hippel, 1993), and frequent information transfer (Allen, 1986; Bastien, 1987; Carter and Miller, 1989), generally suggesting that the benefits from accessing such knowledge bases can only be appreciated in the long run, when the coordination costs resulting from the interaction-specific investment can be appropriately depreciated.

All these procedural coordination mechanisms expose existing routines to the new ones accessed by interacting, increasing the variance of the knowledge base and activating selection processes to determine what will be retained. Differences in the knowledge scope of the relationship would have therefore different impact on whether or not partners have the opportunity to learn from the interaction. More specifically, we can formulate the following hypothesis:

H2: The higher the knowledge scope of the relationship, the greater the learning opportunities of the relationship.

At any level at which the problem solving occurs, it involves the identification of a set of inter-related tasks (von Hippel, 1990). The higher the level of information which needs to be accessed to complete each individual task, the more individual task completion depends on others' actions (Galbraith, 1974), and task interdependencies arise (Thompson, 1967). Assuming that the tasks are partitioned among several actors, one can use two different but related strategies to influence the process: (a) specify the tasks so as to minimize the need for problem-solving across task boundaries (Galbraith, 1973; Duncan, 1976), (b) reduce the cost of engaging in a given level of problem-solving across boundaries (Tushman, 1978; Allen et al., 1980; Katz and Allen, 1985). The first set of actions requires analyzing the tasks to be partitioned and sorting them in an interdependency hierarchy, to be used to arrange the final task partitioning choice. The second set of actions focuses on the use of coordination mechanisms to ease cross-boundary problem solving (Iansiti, 1995a; 1995b).

Task inter-dependencies in organization problem solving routines profoundly affect innovative processes. According to Henderson and Clark (1990), we can distinguish between two different types of problem solving activities: component-related and integration-related. The first type of activities refers to the understanding of characteristics of each specific part involved in the realization of a product. The second type of activities refers to the capability of integrating interrelated components. This distinction, building on a physical representation of relevant knowledge embedded in the product affected by the development, articulates the information processing notion of task-interdependency. On the one hand, problem solvers might have to focus on component related concepts leaving the integrating mechanisms untouched, and therefore not impacting the existing interdependency structure. On the other hand, the nature and characteristics of the inter-dependency among the tasks might in and of itself be a domain of specific problem solving activities.

von Hippel (1990) proposes that dividing the tasks among separate actors, whenever problem solving activities on such tasks are not likely to generate the need for additional problem solving activities in other parts of the project, increases the efficiency of the joint work. Several project management techniques use a similar logic to approach the organization of multiple tasks. Traditional optimization techniques such as PERT and CPM group tasks according to their overall time impact on the project, distinguishing between those on the "critical path" from those not on the critical path. Any delay in the completion of the former will cause a delay of the overall project, while the latter can be more flexibly managed. Similarly, functional design tools such as the House of Quality (Hauser, 1985) or some recent developments in clustering algorithms (Eppinger et al., 1990) try to group tasks on the basis of their interdependencies to increase project efficiency. We can therefore expect the following:

H3: The lower the interdependency of the tasks performed in the relationship, the greater the efficiency of the relationship.

The higher efficiency deriving from a partitioning of tasks low on interdependency can essentially be attributed to the lower coordination costs required by assigning the work to separate actors, who can complete it autonomously and then easily transfer it. Again, once the partitioning choice has been made, there is no further need for articulate and frequent interactions among the parties. On the contrary, they are limited by design. The increased efficiency, therefore, indirectly limits potential learning processes.

The type of coordination mechanisms chosen for efficiency reasons, in fact, do not promote the interactions needed for complex knowledge exchange to occur. While coordination costs might clearly be higher, interactions among highly interdependent activities set the opportunities to reconsider initial solutions. In a way, the need for coordination attracts attention to a larger set of problems than with low interdependent tasks. Conversely, the role and importance of joint problem solving increases and, as we have seen before, learning processes are fostered. We can therefore formulate the following hypothesis:

H4: The lower the interdependency of the tasks performed in the relationship, the greater the efficiency of the relationship.

The hypotheses developed so far establish linkages between the type of relational activities and their different consequences on partners' outcomes. This is important for two reasons. First, we can recognize up front that we have a wide choice of possible alternatives in establishing outside linkages and that the characteristics of the problem solving activities involved can be used to select the most appropriate link. Second, the selection among the alternatives stems from the identification of the potential outcome, distinguishing between efficiency-effects and learning-effects, thus linking expected and desired outcomes with structuring alternatives.

The two dimensions used to characterize problem solving activities, however, in practice also interact (Thompson, 1967). Let's think of a renovation building, for example, a typical project involving the interaction among several independent subcontractors, usually coordinated by the prime contractor. For the lighting of the different rooms, the prime contractor might hire a light-architect to choose the appropriate lamps and accessories providing him with detailed information about the wiring lay-out. This is a typical case in which the relationship is focused on a low interdependent activity, although the freedom given to the light architect to choose the type and style of lamps and accessories characterizes the relationship also as involving a wide knowledge scope. The problem is not limited to the determination of the amount of light required for any given environment, but also on how the lighting should be used to give character to the building, given a fixed wiring layout. If the prime contractor invites the light architect to define the wiring as well, we then face a relationship still characterized by a wide knowledge scope, but also generating a high level of task interdependency. Decisions on wire-layout affect the positioning of other pipes and tubes in the walls, the order in which the different facilities are installed, and so on.

To distinguish among the different possible relationships considering at the same time both the level of task-interdependency and the knowledge scope, we can represent the framework as in figure 4.1 and distinguish among four possible cases. In cases of type A, the need for coordination among the parties is most limited. The boundaries of the activities are clearly defined up-front by one of the actors and the related work does not affect the rest of the project. The established relationship will live a life of its own. The actor involved is given specific goals and its task is to meet them. Both the limited scope of the knowledge involved in the transaction and the low level of task interdependency do not require any specific investments in the relationships. These characteristics sustain efficiency, but do not generate opportunities for learning from the interaction.

Knowledge scope		**Level of task-interdependency** *Low*	**Level of task-interdependency** *High*
	Low	Cases A: One of the partners identify the relevant design specifications and subcontract to the other the detailed definition of functional parameters for components or subsystems with low task interdependency	Cases B: One of the partners identify the relevant design specifications and subcontract to the other the detailed definition of functional parameters for components or subsystems with high task interdependency
	High	Cases C: One of the partners subcontract to the other both the identification of the relevant design specifications and the detailed definition of functional parameters for components of subsystems with low task interdependency	Cases D: One of the partners subcontract to the other both the identification of the relevant design specifications and the detailed definition of functional parameters for components of subsystems with high task interdependency

Figure 4.1 - Combining knowledge scope and level of task interdependency to understand relational activities.

Type D cases have similar effects, albeit for different reasons. If the tasks are highly interdependent, in fact, their partitioning among different actors should be limited to avoid costly coordination investments. Yet, this choice implies that all the resources needed to complete such activities are available internally, which might not necessarily be the case. Studies on product development in the automobile industry have identified several cases in which the car manufacturer delegates entirely to a specialized supplier the identification of the solution domain as well as the detailed specification of the selected alternatives for components with high interdependencies with the whole project (Clark, 1989; Clark and Fujimoto, 1991). Design responsibilities to integrate the component with the rest of the project, on the contrary, are retained by the manufacturer. On the one hand, shifting responsibility and control over the activities results in greater autonomy and, conversely, in lower need for interaction among the parties, enhancing the overall efficiency of the relationship. On the other hand, the absence of substantial interaction with the partner knowledge base decreases the chances to challenge the internal set of competencies. The increased efficiency will therefore be accompanied by fewer opportunities to learn from the interaction. We can therefore formulate the following hypotheses:

H5a: The fit (high-high, low-low) between the knowledge scope and the level of task interdependency of the relationship will have a positive impact on the efficiency of the relationship.

H5b: The fit (high-high, low-low) between the knowledge scope and the level of task interdependency of the relationship will have a negative impact on the learning opportunities of the relationship.

To retain a complete control of the process, one might be tempted to limit the type of problem solving activities performed outside when the level of task interdependency is high, by shifting responsibilities to the identification of predetermined functional parameters. B cases capture these situations. However, if the identification of the relevant functional parameters has not been appropriate from the beginning, the relationship will require numerous iterations among the parties and the need for specific coordination and communication to reconsider the problem and find an appropriate solution, with a negative impact on the efficiency of the relationship. The only contribution from outside actors, in fact, will be limited to the pre-specified domain, without questioning the overall solution space. Although certainly costly, this type of relationships generates the conditions typical of learning by mistake processes, when initial ideas are tested against their feasibility by forcing a specific solution domain on third party activities, and corrections are triggered by the emergence of discrepancies (Levitt and March, 1988).

In C cases the situation is opposite. Concerns over the potential effect on the overall project of other agents focus the interaction on tasks low on interdependency. However, the recognition of the limits of internal competencies on the specific domain suggest to grant to the partner complete freedom in the knowledge scope domain. The shift of complete responsibility in the identification the design concept and on the definition of the relevant functional parameters provide opportunities for more articulate interactions among the parties. Indeed, this type of relationships represents the best option to access outside knowledge sources while limiting the impact of this process on the overall project. To complete the specification of the link between the type of problem solving activities being partitioned and the relationship outcome, we can formulate the following hypotheses:

H6a: The misfit (high-low, low-high) between the knowledge scope and the level of task interdependency of the relationship will have a negative impact on the efficiency of the relationship.

H6b: The misfit (high-low, low-high) between the knowledge scope and the level of task interdependency of the relationship will have a positive impact on the learning opportunities of the relationship.

4.3 Empirical analysis

To investigate the link between the content of the relationship and its outcome implications I focused on supplier-manufacturer relationships. Two very different aspects of supplier-manufacturer ties can be identified in the research literature: the first is concerned with the role of suppliers' relationships in building strengths in manufacturing (Nishiguchi, 1987; Lamming, 1989; Cusumano and Takeishi, 1991). The emphasis here is on improvements of the production process due to suppliers' involvement in quality control practices and a better integration of all parties in the production plan. The second approach tackles the roles, if any, that suppliers are called to play in the development of new products (Imai et al., 1985; Clark, 1989; Hakansson, 1989; Helper, 1989; Lipparini and Sobrero, 1994). The current study continues along this second type of approach to vertical relations with two main objectives deriving from the previously developed theoretical framework: (a) to show the performance implications of different types of vertical relationships, and (b) to explore the role of coordination mechanisms in this process.

4.3.1. Research design

Data on 50 supplier-manufacturer relationships were collected in a longitudinal field study of three new product development projects, conducted during 1995 in three different business units of one the largest European major home appliances manufacturers. The study was conducted in three stages. First, projects were selected through extensive interviews with top management to meet three criteria: (1) coverage of the whole innovativeness domain, defined as the extent to which the project represented major or minor departures from the strategic business unit's (SBU) existing market and technical competencies, (2) recency, to account for both memory retrieval problems in the analysis of past events (Larsson, 1993) and industry specific development cycles, and (3) analytical representativeness (Yin, 1994),[1] to select projects which were considered to be typical of their kind and to avoid outliers, i.e. unusual or critical cases.

Following these criteria, three projects in three different SBUs were selected. The first two projects were still under development during the data gathering, while the third one had already reached the commercialization stage about 9 months before. One project (Project 1) is about a radical innovation requiring a complex blend of actions on the product, the process and the organizational side. The second one (Project 2) involves the re-engineering of an existing product family, while the third one (Project 3) is in between the two and regards the introduction of a new product family that is strongly technically and commercially anchored to existing ones.

[1] It is important to distinguish between analytical and statistical representativeness. In the first case, the discriminant criterion is the adherence of the selected observation to the logical categories defined up front. In the second case, instead, it is defined by the attributional properties of the sample with respect to the larger population it is a part of. In the first case, applied in this study, it suffices to define certain analytical dimensions and find matches between them and the selected cases. In the second case, instead, it is necessary to define up front the proper population and insure that sampling criteria guarantee a balanced sample.

The second phase of the research was dedicated to an in depth analysis of each single case to gain a full understanding of the development context. The data resulting from this second phase are presented elsewhere (Sobrero, 1996), and make explicit the processes through which inter-organizational relations represent opportunities to generate variance in the actor routine base, promote selection processes and favor the retention of imported knowledge. In addition to that, during this second phase all the interactions with suppliers that occurred during the project development process were identified. Using the sets of components and machinery related to the new project as the reference base, project managers were asked to identify all the cases in which suppliers were asked to perform some development work. The initial information was cross-checked with all other project team members and the business unit Purchasing manager. A total of 50 development supply relationships resulted from this process, 21 for the radical project, 18 for the incremental one, and 11 for the intermediate one.

The third research phase built on this set of interactions identified during phase two and was dedicated to data gathering at the individual relationship level, the unit of analysis of this empirical study. Using direct interviews, internal archives and structured questionnaires, individual relationship data were collected for each of the 50 interactions identified. Responses were further checked through a second round of direct interviews with the project managers. The final data-set can be thought of as three ego-networks (see figure 4.2). Technically ego-networks identify the relational set of the sampled egos (Marsden, 1990). In this case, for each of the three egos - i.e. a SBU developing a project - information was collected on all the relationships established with others - i.e. the suppliers. The approach has two main advantages. First, it allows determining from the beginning the perspective taken in the analysis of the relationships examined by identifying up-front the egos, in this case that of the manufacturer. Second, by collecting data on all the relationships established by an ego, it increases the variance in the relational set examined. These two features are particularly relevant for this research because (a) the former stresses the importance of capturing an entire relational set for monitoring the structuring decisions of the central actor, (b) the latter provides access to different types of relationships, thus allowing the comparison among alternative choices. The following section presents the data gathered for each single relationship in detail and operationalizes the theoretical concepts developed in the first part of this paper.

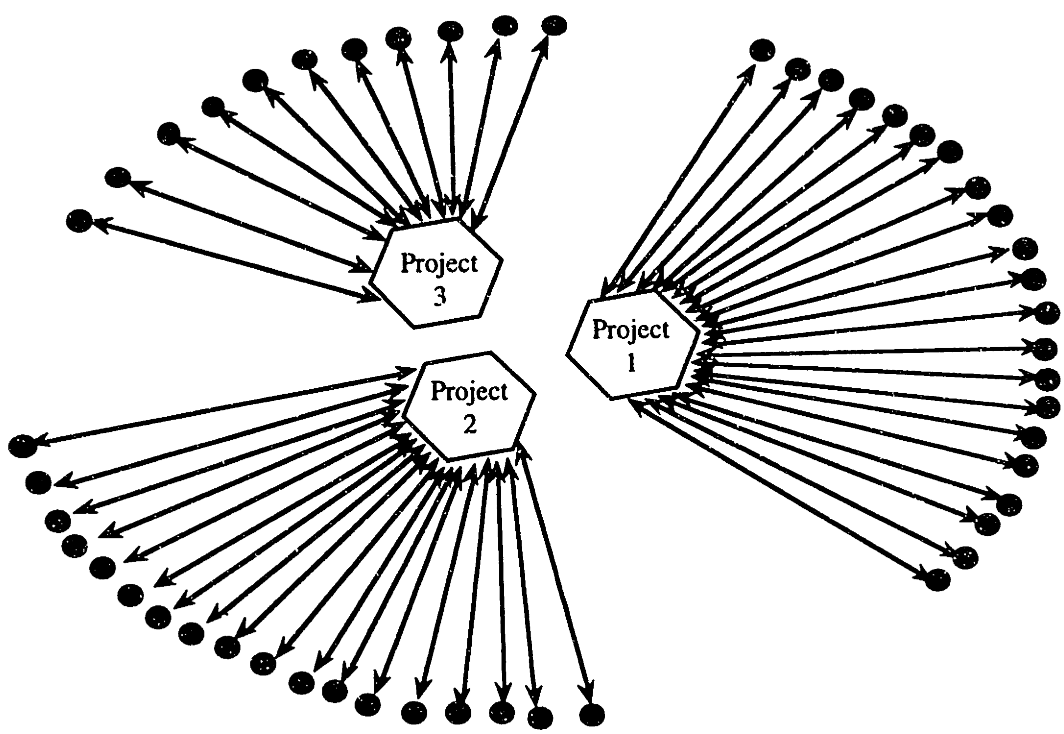


Figure 4. 2 - The sample.

4.3.2 Variables definition and operationalization

Three aspects of a relationship are of conceptual interest here: its content, its coordination and its outcome. The content of the relationship tackles the nature of the transaction between the parties. The coordination captures how the parties chose to structure the transaction. The outcome here defines the consequences of the relationship for one of the actors, in this case the manufacturer. The following paragraphs describe how these concepts were operationalized. Table 4.1 at the end of this section reports a summary of all the variables included in the analysis and their conceptual meaning.

4.3.2.1 The content of the relationship

Two separate variables are used to classify the relationships according to their content. The first variable (KNOWLEDGE SCOPE) focuses on the domain of suppliers' problem solving activities. It is used to distinguish between relationships where the supplier worked on the development of manufacturer pre-identified functional parameters, and relationships where the supplier was also responsible for the definition and choice of the design concept. The variable is a dummy coded 0 for the first type of relationship (low knowledge scope) and 1 for the second type (high knowledge scope).

The second variable (LEVEL OF TASK INTERDEPENDENCY) focuses on the impact of supplier activity on overall project interdependencies. It distinguishes those relationships involving work on a specific component which has limited influence on the other parts of the project, from relationships whose outcome is more likely to determine a larger impact on the project. The variable is also a dummy coded 0 for the first type of relationship (low level of task interdependency) and 1 for the second type of relationship (high level of task interdependency).

To code each relationship accordingly, extensive direct interviews were conducted with the project manager, articulating these two conceptual dimensions through the operational activities performed during the project by the supplier. After an initial round of interviews, a first classification of the relationships discussed was provided to the interviewee, together with an account of the evidence emerged during previous meetings, which was used to guide the process. Possible disagreements were resolved during an additional round of interviews and through the use of internal documents.

The combination of the two variables provides an operationalization of the four different categories of possible interaction types identified in figure 4.1. In the category A, all the design work and the related problem solving is done internally and the supplier receives detailed drawings and technical specifications to be met for a component which is not considered to critically affect other parts of the overall project. The supplier's action domain is therefore limited to these technical orders and has little consequences on the rest of the project. This group represents the traditional subcontracting approach in new product development and is therefore labeled "Traditional Subcontracting".

The second category, type B, captures the situation wherein the supplier action domain is confined to responding to manufacturer determined specifications, but for components which may critically impact other parts of the project. The problem solving efforts and responsibilities of the supplier are therefore limited by the relevant action domain, but its potential effects on the project itself are higher. In this type of relationship, suppliers are recognized as an important source of knowledge, but the characteristics of the component suggest limiting their freedom in problem solving activities. In a way, by being limited to the functional parameter domain, they are integrated into the manufacturer's problem solving logic and process. I label this type of relationship "Integrated Subcontracting".

In category C the problem solving activity is confined to components with low interdependency with the rest of the project. However, the manufacturer here limits its own activities by selecting an area of the project and delegating to the supplier the identification of possible solutions. The supplier domain of action is therefore widened, albeit limited to areas of low influence on the overall project. In this type of relationship, the manufacturer tries to access a specific knowledge domain of the supplier, without limiting its potential outcome by a predetermined set of solutions. I will call this type of relationship "Advanced Subcontracting".

In the fourth category, D, suppliers are responsible for concept design problem solving activities for highly critical components. Despite the potentially high influence on the overall project, suppliers are given freedom to define the solution starting from the concept design domain and then moving to the functional parameter domain. This practice has been highly documented in Japanese firms as a way to reduce the overall product development time and costs (Imai et al., 1985; Clark and Fujimoto, 1991). Components developed according to these arrangements have been identified as Black Box parts. I will therefore refer to this type of relationships as "Black Box Subcontracting".

4.3.2.2 The outcome of the relationship

To distinguish between efficiency effects and learning effects, two different performance measures were collected. Both measures reflect performance from the manufacturer's perspective. The data collected do not permit to capture a dyadic notion of performance, or to consider the outcome of the relationship from the supplier's point of view. In this sense, they are a one-sided evaluation of relationship outcome.

For each single relationship, the project manager was asked to fill out an evaluation questionnaire containing 8 items on a 5 point Likert scale. Six items were used to obtain a judgment of the performance in terms of its efficiency (i.e. schedule deadline, cost objectives, quality levels, etc.). Two items were used to capture the learning outcome of the relationship. One of these two items was used to assess whether project managers felt that his organization had learned something new from the interactions with the supplier. The other item asked to what extent solutions developed during the interaction were subsequently used in other projects.

Three different approaches were followed to validate these measures. First, the correlation coefficients within the two sets of items were compared. Both were very high and statistically significant. The average correlation coefficient for the Efficiency items was .62 ($p<.001$) and the correlation between the two Learning items was .57 ($p<.001$). Second, the whole set of items was subjected to a Principal Component analysis. The first two eigenvalues accounted for 75 percent of the variance (50 percent and 25 percent respectively). The EFFICIENCY items all loaded strongly and positively on the first (Component Loadings varied from .75 to .93) and not on the second (Component Loadings varied from -.20 to .20), while the LEARNING items loaded strongly on the second (Component Loadings .85 and .91) but not on the first (Component Loadings -.04 and .08). Finally, Cronbach's α coefficient was calculated for both constructs (EFFICIENCY Cronbach's $\alpha = .91$, LEARNING Cronbach's $\alpha = .72$).

These analyses confirmed the distinction between the two types of outcomes as measured, and suggested compounding the single item indicators into two indicators. To create the EFFICIENCY indicator, for each observation all the responses to the six items were summed, weighted by their corresponding component loadings on the first eigenvalue. Similarly, to create the LEARNING indicator, for each observation all the responses to the two items were summed, weighted by their corresponding component loadings on the second eigenvalue.

4.3.2.3 The coordination of the relationship

In chapter 2 I used the term procedural coordination mechanisms to define the means used to govern the mutual exchange of information for the combination of agents or functions towards the production of joint results. This concept identifies the organizational mechanisms used to structure the relationship among the different parties involved. It builds on the organizational design tradition to extend its concepts and findings to the inter-organizational domain. It is through the lenses of these coordination mechanisms, in fact, that the efficiency and learning implications of different types of relationships can be better understood. To operationalize this general concept, I focus on four different dimensions which can be leveraged to enhance integration: frequency of communication, type of information media used to exchange information, suppliers' early involvement in product development activities and timing of upstream-downstream communication flows (Clark and Fujimoto, 1991).

Research on communication shows the importance for faster and more effective solutions of frequent contacts among the subjects involved in problem solving activities (Allen, 1986; Bastien, 1987; Carter and Miller, 1989). In addition, numerous findings stress the role of different information transferring media in enhancing the process. Direct verbal contacts and personal interactions, either through meetings or phone calls, allow faster recognition than written communication of potential conflicts among interdependent tasks. Some new information technology tools, however, such as a shared CAD platform seem to be combining effectively the richness of information deriving from oral communication and its more rigorous formalization through written codification such as drawings, specifications and the like (Orlikowsky, 1993). To capture this integration dimension, for each relationship I determined how often the supplier and the manufacturer interacted during the project and what information media they used predominantly.

In measuring frequency of information exchange a well known problem is that of determining an appropriate anchoring lag for the observed setting (Allen, 1977). After several in depth interviews in all the projects with different people at different levels of the organization, the appropriate anchoring point was considered to be a month. Communication frequency was therefore considered to be high if the manufacturer and the supplier exchanged information more often than once a month, medium if they did so about once a month, and low if less than once a month. Data on information frequency were coded using a 5 point Likert scale (1=low, 5=high).

The prevalent way through which the manufacturer and the supplier interacted during the project was assessed by predetermining a set of 5 options, derived from previous research on communication in problem solving, ordered hierarchically following a Gutman scale logic.[2] The options included in increasing order were: (1) drawings, (2)

[2] In Gutman scales, the options are ordered so that any lower rank one is included in higher rank ones. This is clearly the case for information media. During the interviews, it emerged strongly that, for example, while drawings were always exchanged among the parties when interpersonal contacts were also widely used, the reverse was never true. The proposed ordering formalizes these observations, reflecting two assumptions derived from communication theory (Rogers and Agarwala-Rogers, 1983). First, higher options are richer ways of transferring information. Second, higher order options are usually accompanied by several other lower order ones. The richer the information transferring media used, the wider the overall set of information media used.

faxes, (3) meetings, (4) personal communication among the project members and (5) electronic data exchange, through the use of common platforms. Each manufacturer-supplier relationship was assigned a "media effectiveness" value between 1 and 5 depending on the prevalent communications option used during the project for that specific relationship.

Clearly these two dimensions of communication are not independent, and that was reflected in the data. The variables were highly and significantly correlated (.71, $p<.001$). I therefore combined them in one single indicator of COMMUNICATION ACTIVITY adding the scores on each variable weighted by the component loadings obtained from a principal component analysis run on the whole set of observations for the two variables.

The other two dimensions of integration, suppliers' early involvement and the extent to which sequential rather than overlapping modes of problem solving are used, take into consideration the results of numerous studies on effective ways to increase product development performance. For each relationship information was collected on two critical dates: the first date the supplier was contacted during the project and the date the purchasing contract was signed. This second date follows by about one month the official request for proposals made by the manufacturer to a set of interested suppliers.

The following index was constructed to indicate how early the supplier was involved (EARLY INVOLVEMENT). First, the number of days between the date of first contact and the date of project first commercialization was used to show how far from the end of the project the first contact occurred. This number was then normalized by the total length of the project, measured as the difference in days between the date of project first commercialization and the date of beginning of the project. The resulting index varies between 0 (latest involvement) and 1 (earliest involvement).

Finally, to reflect the extent to which activities were organized in an overlapping rather than in a sequential way another index was constructed (OVERLAP). I first took the difference between the date the contract was signed and the date of first contact with the supplier, measured in days. The longer this span, the more both parties had a chance to overlap their activities. The shorter this time, the more likely it is that first the manufacturer performs its part of the activity and then shifts it to the supplier, similarly to how an R&D department might first define the product specifications and then turn them over to the engineering department to complete the engineering-for-manufacturing.[3] This index was then normalized against the longest time span within each of the three projects, and varies between 0 (perfectly sequential) and 1 (completely overlapping).

4.3.2.4 Controls

Data were collected from three different projects. A group variable was therefore used to control for possible differences among the projects. Research shows the importance of the existence of previous contacts among the parties in explaining relationship patterns (Roberts, 1967; Anderson and Weitz, 1989; Heide, 1994). Moreover, the length of time since the contact was first established also emerged as a critical variable (Heide and Miner, 1992). For each manufacturer-supplier relationship I recorded the existence of a previous contact with the supplier and how long the two had been interacting. A dummy coded 0 indicated no previous contact was established before that specific project, and 1 otherwise. The length of any pre-existing relationship was

[3] The index really measures the opportunity for overlapping to occur rather than its effective presence in one particular relationship. After several discussions with the people involved in the projects analyzed, however, this measure seemed to be capturing adequately the presence of a sequential rather than overlapping approach in organizing the design work with suppliers.

measured by the number of days from the first time the manufacturer had a contact with the supplier and the beginning of the project.

Data for two other aspects were also collected to control for possible threat to internal validity. Conceptually, the economic value of the tie has long been claimed as the central explanatory variable for understanding the outcome of an inter-organizational relationship. Cost-based indicators have been used to operationalize asset-specificity as well as relational complexity (Monteverde and Teece, 1982; Joskow, 1987; Heide and George, 1990). In this case I operationalized the relationship's economic value as the cost of the single component being developed expressed as a percentage of the full manufacturing cost of the final good being produced. The full manufacturing cost was chosen as the benchmark over possible alternatives (i.e. the market price, the project cost-target), since it is the base internally used to set projects' financial goals.

Related to the notion of economic value of the exchange is the way in which the transaction is legally governed. It refers to the choice of what I called in chapter 2 contractual coordination mechanisms. The classical argument is that more precise and detailed definitions of the possible contingencies and of the clauses to govern such contingencies will increase the outcome efficiency by limiting the chances for the emergence of opportunistic behavior and deviance from original agreements. The results of the meta-analysis presented in chapter 2 found strong support from previous research of these findings.

To operationalize contractual coordination mechanisms, the Purchasing Director was interviewed in each of the three business units in order to characterize each single contractual arrangement. Using previous studies and discussing these issues during the interview, ten possible elements worth specifying in a contract were identified.[4] Each of these elements was then associated with a 5-point Likert scale to measure the extent to which one particular element had been specifically negotiated with the supplier (5), rather than regulated according to some standard practices normally applied to similar contracts (1). These data account at the same time for both the breadth of contract definition (how many contingencies are considered), and its depth (to what extent there was a specific investment in contractually regulating a relationship). The scores on each item were added up and then divided by 10 (for the 10 items), generating a final indicator between 0 (no element included in the contract) and 5 (all elements explicitly negotiated for that specific relationship included in the contract).

Table 4.1 - The variables used in the analysis: a summary

Variable	Conceptual meaning	Calculations	Coding
Knowledge scope	Distinguishes between relationships in which suppliers' problem solving activities involve concept design definition vs. functional parameters specification	Dummy variable	0 = low knowledge scope 1 = high knowledge scope
Level of task-interdependency	Distinguishes between relationships in which suppliers' problem solving activities involve low vs. highly interdependent tasks	Dummy variable	0 = low interdependent task 1 = high interdependent task
Efficiency	Measures relationship efficiency as the ability to meet deadlines, respect budgets, etc.	A composite measure of six 5-points Likert scale items	Positive, real

[4] The elements were: price, quantity, lead time (i.e. time of response to manufacturer order), quality levels, control practices, exclusivity clauses, volume elasticity (i.e. willingness/ability to adapt to changes in the quantity ordered quickly), penalties and fines, contract renewal, and purchase order activating procedures.

Table 4.1 - continued from previous page

Variable	Conceptual meaning	Calculations	Coding
Learning	Measures relationship learning as the ability to influence future design activity	A composite measure of two 5-points Likert scale items	Positive, real
Early involvement	Measures how soon in the life of the project the relationship was activated	The difference in days between the end of the project and the date of first contact with the supplier, normalized by the total length of the project	Between 0 (latest involvement) and 1 (earliest involvement)
Overlap	Measures the extent to which overlapping vs. sequential problem solving arrangements were used between the two parties involved	The difference in days between the day the purchasing contract was signed the date of first contact with the supplier, normalized by its maximum value in the project	Between 0 (completely sequential) and 1 (completely overlapping)
Previous relationship	Checks for the presence of an established relationship prior to the specific one observed between the parties	Dummy variable	0 = no previous relationship 1 = previous relationship
For how long	Measures the length of any previous relationship between the parties	The difference in days between the beginning of the project and the date of first ever interaction with the supplier	Positive, integer
Component cost	Measures the economic value of the relationship	The cost of the component over the total manufacturing cost of the final product	Positive, real
Contract spec	Measures the extent of use of contractual arrangements and its level of specification	A composite measure of 10 items on a 5-point Likert scale, normalized by the number of items.	Between 0 (no element included in the contract) and 5 (all elements specifically negotiated and included in the contract)

4.4 Results

The data analysis in this section moves through three separate stages. First, univariate statistics are used to show the characteristics of the sample, assess the potential influence of inter-project differences and check for multicollinearity among the variables selected. Then a dummy-regression model is employed to test for the explanatory power of the relational content framework developed, controlling for other possible sources of variance in the sample, using both the Efficiency and the Learning outcome measures. Finally, individual coefficients are examined to test the hypotheses developed in section 2.

4.4.1 Univariate statistics

Table 4.2 reports the means, standard deviations and correlation coefficients for all the variables previously defined. Table 4.3 partitions the whole data set along the three projects and reports the tests for differences among the groups for all the different variables.

A first look at the data confirms the importance of previous relationships in the sample. About 82% of the cases examined, i.e. 41 cases, involved suppliers with whom the manufacturer already had interacted before the beginning of the projects for about 10 years, and there are not significant differences among the groups. This might be a first explanation for the limited use of contractual arrangements to govern the relationship. On average, only two elements out of the possible ten were fully specified for a particular relationship, and while there seem to be differences among the projects ($F\text{-test}_{2,47} = 13.042$ $p<.001$), the nighest value reported (1.78, for Project 2) still indicates a very limited use of the contractual leverage.

Table 4.2 - Univariate statistics and bivariate correlations.

	Var	Mean	StDev.	N	1	2	4	5	6	7	8	9	10	11
1	Knowledge scope	.34	.48	50	-									
2	Level of task-interdependency	.62	.49	50	.21	-								
3	Efficiency	17.95	4.85	50	.23	-.15	-							
4	Learning	5.16	2.19	50	.49***	.37***	.11	-						
5	Early involvement	.61	.15	49	.14	-.22	-.16	.03	-					
6	Communication	3.83	1.45	50	.10	.42***	-.15	.38***	-.03	-				
7	Overlap	.49	.35	49	-.01	.33**	-.07	.21	.42***	.29**	-			
8	Previous relationship	.82	.39	50	.01	.17	-.04	.04	-.03	.18	.04	-		
9	For how long	3502	3059	49	-.02	-.10	.12	-.11	.06	-.23	-.13	.55***	-	
10	Component cost	1.40	1.82	50	.20	.26*	-.31**	.13	.13	.28**	.27*	.06	-.23	
11	Contract spec.	1.29	.63	50	-.12	-.16	-.27*	-.14	.37***	.01	-.15	-.15	-.20	.07

* p<.1, ** p<.05, *** p<.01

Table 4.3 - Sensitivity analysis to test for the presence of a Project effect: means and standard deviation by group.

Variable	Project 1 (n=21)	Project 2 (n=18)	Project 3 (n=11)	Test of Project Effect
Knowledge scope	.48 (.51)	.22 (.43)	.27 (.47)	F-test $_{2,47}$ = 3.361 p-level <.05
Level of task interdependency	.62 (.50)	.44 (.51)	.91 (.30)	F-test $_{2,47}$ = 1.537 p-level = .266
Efficiency	20.85 (4.66)	16.05 (3.96)	15.51 (3.8)	F-test $_{2,47}$ = 8.536 p-level <.01
Learning	5.55 (2.51)	4.42 (2.11)	5.62 (1.32)	F-test $_{2,47}$ = 1.652 p-level = .203
Early involvement	.62 (.16)	.62 (.17)	.56 (.05)	F-test $_{2,46}$ = .353 p-level = .705
Communication	4.23 (1.36)	3.34 (1.31)	3.87 (1.70)	F-test $_{2,47}$ = 1.897 p-level = .161
Overlap	.62 (.26)	.19 (.24)	.76 (.30)	F-test $_{2,46}$ = 20.119 p-level <.001
Previous relationship	.86 (.36)	.83 (.38)	.73 (.47)	F-test $_{2,47}$ = .411 p-level = .666
For how long	3180 (2579)	4331 (3811)	2732 (2343)	F-test $_{2,46}$ = 1.125 p-level = .333
Component cost	1.23 (1.41)	1.03 (1.35)	2.26 (2.84)	F-test $_{2,47}$ = 1.676 p-level = .198
Contract specification	1.1 (.20)	1.78 (.81)	.88 (.25)	F-test $_{2,47}$ = 13.042 p-level <.001

To better examine this pattern, figure 4.3 reports the distribution of the responses for the three projects for each of the items included. Price and quantity elements are present in all the contracts observed. This is not at all surprising. What is more surprising is to observe that among all the other possible elements, only three (lead time, quality levels and control practices) are somehow explicitly part of the negotiation, and that exclusivity clauses are included in only 3 cases out of 50. All the other issues (volume elasticity, penalties and fines, contract renewal, purchase order activation procedures) are never negotiated within the contract. This pattern of low reliance on the contractual governance of the relationship is similar among projects, with a little more attention given to it by Project 2. In general, however, the contracts used to govern the relationships observed are neither specific nor particularly detailed.

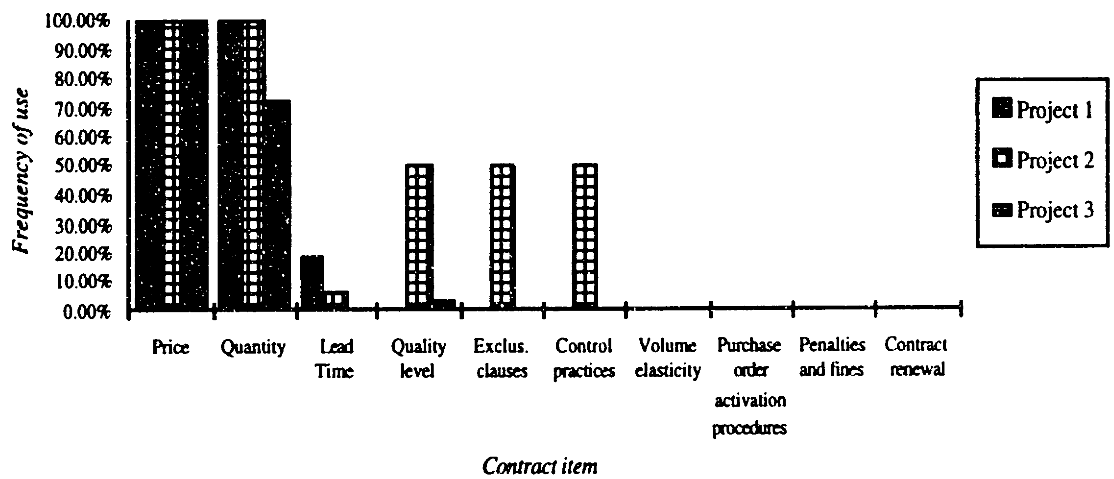


Figure 4. 3 - Contract items by frequency of use and project.

These similarities in the relational set are extended also to the economic value of the interaction. Considering the whole set of relationships established in each of the three projects, the total value of all components developed through some kind of interaction with the suppliers is 27% for Project 1, 19% for Project 2 and 25% for Project 3. On average, the cost of each single component developed with a supplier is about 1.4% of the total manufacturing cost and there are not statistically significant inter-project differences. The variance in this case is higher, with some components worth up to 9% of the final manufacturing cost of the product.

Table 4.4 - Average value of supply by relationship type and project: % of manuf. cost.

	Project			
Type of relationship	1	2	3	Full sample
Traditional	3.07	7.26	---	10.33
	(n=5)	(n=10)		(n=15)
Integrated	8.75	3.35	15.20	27.30
	(n=6)	(n=4)	(n-8)	(n=18)
Advanced	4.47	---	.50	4.97
	(n=3)		(n=1)	(n=4)
Black Box	10.35	7.98	9.10	27.43
	(n=7)	(n=4)	(n=2)	(n=13)
Total	26.64	18.79	24.80	

Since there seem to be at least some differences within the projects with respect to the type of relationships established (inter group differences for: Level of Knowledge F-test $_{2,47}$ = 3.361, $p<.05$; Level of interdependency F-test $_{2,47}$ = 1.537, n.s.), it is interesting to compare the average value of the component among the possible different relationship types (see Table 4.4). In Project 1 all the different options are used; in Project 2 no supplier is assigned responsibility for the definition of design concepts of components or subsystems moderately interdependent with the rest of the project; and in Project 3 only one supplier is working on similar types of components and none working on the specification of functional parameters of moderately interdependent ones. This difference among the projects led to a moderate representation within the sample of what we previously labeled "Advanced" types of relationships, which should be accounted for in the rest of the analysis. After controlling for this aspect, however, the value of the components developed is spread among the different types of relationship and there are no statistically significant differences either among the groups, or among the projects.

On average, relationships are activated in the first half of the project life (mean of Early Involvement =.61), and although there is variance in the sample there are no significant differences among the projects. The overall level of communication is also high, although it varies among the cases but not across projects. However, while the level of overlap of the manufacturer and supplier problem solving activity seems on average moderate (.49), the disaggregated data show significant differences between Projects 3 and 1 (.76 and .62, respectively) and Project 2 (.19).

4.4.2 The regression model

Three separate sets of regression models were used to test for the role of relationship types in understanding outcome differential, first using the Efficiency measure as the dependent variable and then using the Learning measure as the dependent variable. Within each of the two sets, I specified a baseline model without the relationship effect, and a full model including the relationship effect. Finally, Project dummies were introduced to control for project-effects. Differences in the R-square estimates between the two models are used to assess the overall effect.

The baseline model includes as predictors the Component Cost, the Level of Contract Specification and the Presence (or absence) of a previous relationship. An inspection of the bivariate correlation coefficients between this last variable and the Length of previous relationship shows a high and significant correlation between the two, which suggests a potential multicollinearity problem. The Presence variable was therefore chosen between the two for its easier interpretability. Subsequent sensitivity analysis did not show any significant changes in the model estimates when Length of previous relationship was chosen instead. The analysis of the bivariate inter-correlation among the variables included in the baseline model does not point to multicollinearity within the sample. Since no major project level effect emerged from the previous analysis of the data, no group variable was included in either of the models to increase their parsimony.

To include the relationship effect in the full model, I added the Knowledge Type dummy, the Interdependency Level dummy and a cross product of the two. As a consequence, the intercept of the full model represents the Traditional type of relationships, the Interdependency Level dummy captures the Integrated type, the Knowledge dummy the Advance type and their cross product the Black-Box type. The comparison between the baseline model and the full model therefore tests the importance of considering the type of relationship activated in understanding the relationship outcome. The analysis of the single coefficients provides a direct test for Hypothesis 1, 2, 3, 4, 5a, 5b, 6a, and 6b. Project dummies are then introduced and their overall effect is tested with a Δ R-square test, while individual coefficients are examined to detect specific project.

Table 4.5 - Regression analysis: dependent variable = EFFICIENCY

	Model 1	Model 2	Model 3
Constant	22.181	21.695	24.083
	(2.345)	(2.411)	(2.253)
Previous relationship	-.575	-.565	-1.184
	(1.676)	(1.532)	(1.132)
Cost of component	-1.257**	-.643	-.643
	(.585)	(.553)	(.487)
Contract	-1.543	-1.316	-.833
	(1,115)	(1.029)	(1.129)
Level of task interdependency (A)		-2.901*	-2.497*
		(1.471)	(1.442)
Knowledge scope(B)		.008	-1.492
		(2.314)	(2.121)
A*B		6.330**	6.440**
		(2.887)	(2.664)
Project 2			-3.928**
			(1.458)
Project 3			-4.489***
			(1.553)
n	46	46	46
df	42	39	37
R-square	.142	.371***	.548***
Δ R-square		4.92***	5.53***

* p<.1, ** p<.05, *** p<.01

After eliminating incomplete records, the final sample included a total of 46 observations. Tables 4.5 and 4.6 report the model estimates for both the baseline and the full model, regressed on Efficiency and Learning. In both models the inclusion of the relationship type variables significantly contributes to explaining variance in the outcome variables. In the case of EFFICIENCY, the R-square goes up to .371 from .133 (Δ R-square = 4.92, p<.001), and the improvement in the model is even more substantial in the case of LEARNING, where the R-square increases to .482 from a low .05 (Δ R-square = 10.98, p<.01).[5]

These results suggest that, after controlling for other effects generally associated with the outcome of the relationship, a precise specification of the relationship type is an important explanatory factor in understanding what actors are getting out of inter-organizational ties. Moreover, the consistency of the model in estimating different type of relational outcomes also suggests the appropriateness of articulating such measures, distinguishing between short term and long term effects. The inclusion in the model of project dummies does not statistically affect these estimates. Between project differences exists in EFFICIENCY levels (Δ R-square = 5.53, p<.01), but not in LEARNING levels (Δ R-square = .026, n.s.). However, in both cases the role of the characteristics of the relationship is still a fundamental explanatory element, as the direction and the significance of the Knoledge Scope and Level of Interdependency coefficients are stable even after the inclusion in the model of project dummies.

These conclusions are further strengthened by looking at the individual coefficients. The knowledge scope effect is positively associated with higher levels of learning, providing support for Hypothesis 2. Its association with the Efficiency level of the relationship, however, is trivial and not significant. Hypothesis 1 is therefore not supported. The Level of Interdependence effects, on the contrary, provide support for both

[5] A residual analysis was performed on both full models to check for any violation of the underlying assumptions. A visual inspection of a normal probability plot of residuals, as well as the Liliefor -test (dependent variable EFFICIENCY, p-level = .39; dependent variable LEARNING, p-level = .56) did not show violation of the normality assumption. The coefficient estimates tolerance values did not point to multicollinearity in the data. No evidence emerged either from a visual inspection of the scatter plots and or from the analysis of Cook's d and Hat's H statistics for the presence of outliers or high-leverage points. Finally, the analysis of standardized residuals did not reveal the presence of heteroschedasticity in the observed sample.

hypothesis 3 and 4. Relationships involving components low on interdependency are more efficient than those involving components high on interdependency. The lower levels of efficiency, however, are compensated by higher levels of learning.

Table 4.6 - Regression analysis: dependent variable = LEARNING

	Model 1	Model 2	Model 3
Constant	6.224 (1.162)	3.222 (1.033)	3.270 (1.131)
Previous relationship	-.062 (.831)	.300 (.656)	.228 (.694)
Cost of component	-.200 (.290)	-.378 (.237)	-.354 (.244)
Contract	-.669 (.553)	-.058 (.441)	-.179 (.567)
Level of task interdependency (A)		2.345*** (.630)	2.531*** (.724)
Knowledge scope(B)		4.293*** (.991)	4.539*** (1.065)
A*B		-3.156*** (1.237)	-3.442*** (1.338)
Project 2			.523 (.732)
Project 3			-.084 (.771)
n	46	46	46
df	42	39	37
R-square	.05	.482***	.489
Δ R-square		10.982***	.026

* p<.1, ** p<.05, *** p<.01

The analysis of the coefficients for the cross-products among these two variables shows support for hypothesis 5a and 5b, as well as 6a and 6b. The use of Black-Box type of relationships, when suppliers are given full responsibility for the development of highly interdependent components, on average shows higher levels of efficiency (coeff. estimate = 6.33, p<.05) but lower levels of learning (coeff. estimate = -3.16, p<.001). Once more, these results show the presence of a trade-off between efficiency increasing type of relationships and learning enhancing ones.

4.5. Discussion

The results of statistical analysis of 50 supplier-manufacturer relationships in new product development projects in the European major home appliance industry provide support for two main issues. First, in examining inter-organizational relationships it is important to distinguish different possible types of outcomes. The existence of a trade-off between Efficiency and Learning oriented ties requires a specific, preliminary choice over the possible alternatives to make sure that the original goals are met (see table 4.7). Focusing on the type of problem solving activities is a way to distinguish among the possible alternatives, and select the most appropriate one according to the desired outcome.

Second, a closer look at the characteristics of the knowledge being partitioned informs the selection of the alternatives. Whenever the activities being partitioned generate high interdependencies for the rest of the project, they require more coordination efforts, increasing the governance costs. The lower efficiency is accompanied by higher opportunities to activate the conditions for learning processes to occur. Higher coordination efforts, in fact, mean more opportunities to interact and to access tacit knowledge bases. Similarly, the more freedom is granted to the supplier in the problem solving process, the higher the learning opportunities, albeit, once more, accompanied by comparatively lower efficiency. Interestingly, however, the joint effect of these two dimensions of problem solving has similar effects on the relationship outcome.

Table 4.7 - Summary of results and conclusions from the statistical analysis.

Hypothesis	Results	Conclusions
H1	Not supported	No evidence that relationships involving concept design work being performed by outside agents are less efficient than relationships involving functional parameter definition.
H2	Supported	Relationships involving concept design work being performed by outside agents provide more opportunities for learning than relationships involving functional parameter definition.
H3	Supported	Relationships generating high interdependencies are less efficient than relationships involving low interdependent tasks.
H4	Supported	Relationships generating high interdependencies provide more opportunities for learning than relationships involving low interdependent tasks.
H5a	Supported	Relationships generating low interdependencies <u>and</u> involving functional parameter specification performed by outside agents are comparatively more efficient.
H5b	Supported	Relationships generating high interdependencies <u>and</u> involving concept design work performed by outside agents are comparatively more efficient.
H6a	Supported	Relationships generating low interdependencies <u>and</u> involving functional parameter specification performed by outside agents provide comparatively fewer opportunities for learning.
H6b	Supported	Relationships generating high interdependencies <u>and</u> involving concept design work performed by outside agents provide comparatively fewer opportunities for learning.

To increase the short term gains from inter-organizational product development activities, the options are therefore either to (a) use outside sources as mere traditional subcontractors, assigning them specific tasks to be met for low interdependent project parts, or (b) externalize completely the conception, design and realization of highly interdependent parts, jointly working on their overall integration with the rest of the system. Although apparently risky, if we only consider the interdependence dimension, the knowledge dimension is central to understanding these results. Any limitation on this side, in fact, will generate possible inefficiencies by separating the relevant knowledge base from the responsibility to define a solution. Whenever for highly interdependent components one of the parties identifies the concept design and subcontracts the definition of the functional parameters, it generates a strong knowledge asymmetry, which, considering the importance of the component for the overall project, is likely to propagate possible inefficiencies at the overall project level.

A further look at the data is informative. In particular, it is important to focus on the integration mechanisms used in the different types of relationships, since their use ultimately determines the conditions for learning to occur and the investment required by the relationship. In order to do so, the sample was partitioned using the level of task-interdependency and the knowledge scope dimensions in the four types of manufacturer-supplier relationships identified: Traditional, Integrated, Advanced and Black-Box.

In general, suppliers in all categories are involved rather early in the process (see figure 4.4). The Timing index varies between a low .564 (Integrated relationships) and a high .708 (Advanced relationships) indicating that suppliers are contacted for the first time during the first half of the project. Traditional and Black-Box relationships show similar values (.634 and .614 respectively). In both cases suppliers are assigned tasks which can be carried out rather autonomously and their earlier involvement is key for compressing development time. In contrast, Integrated and Advanced types of relationship show different patterns. Whenever suppliers are given full design responsibility for low interdependent parts, they tend to be contacted very early in the project, giving them time to experiment with different solutions and alternatives. On the contrary, for highly interdependent components, when the design responsibility assigned is limited to specific functional domains, the later supplier involvement shows how problem solving activities at the concept design level have to be completed before these contracts can be activated.

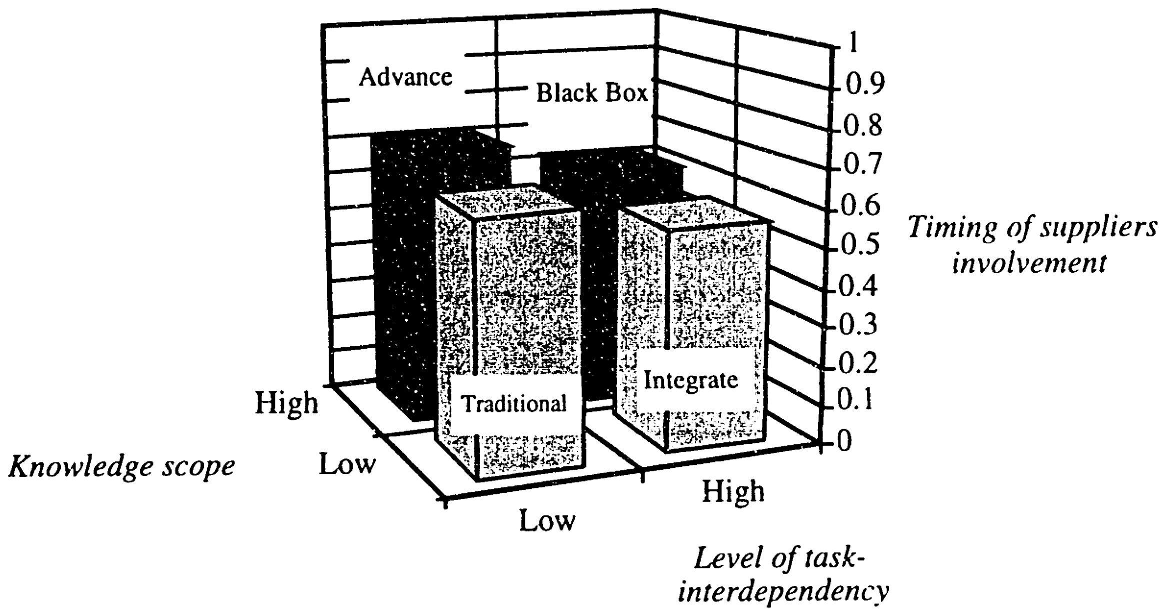


Figure 4. 4 - Timing of supplier's involvement by task characteristics

An analysis of the Communication index complements these observations (see figure 4.5). It captures both the frequency of communication between the manufacturer and the supplier during the project, and the type of information transfer mechanisms used. The Traditional type of relationship shows the lowest values, consistent with the characteristics of activities represented in this category. Typically, in these cases, the supplier is given a very detailed design developed by the manufacturer and is asked to engineer it. Black-Box relationships show a much higher value (3.9), reflecting the higher complexity of the tasks involved, but still lower than Integrated (4.5) and Advanced types (4.3). The highest value for Integrated ties reflects the back and forth process recalled previously. By constraining suppliers' domain of influence to the functional parameter domain, the proposed solutions may fail to take into consideration their interdependency implications. Since the Integrated category deals with highly interdependent components, the result is a frequent exchange of information to correct for these mistakes. In the Advanced category suppliers' freedom in the design of low interdependent components give the manufacturer the chance to experiment with different solutions and verify their ease of integration in the project. This slack, however, needs to be managed through extensive contacts between the parties, which are reflected in the high level of communication observed.

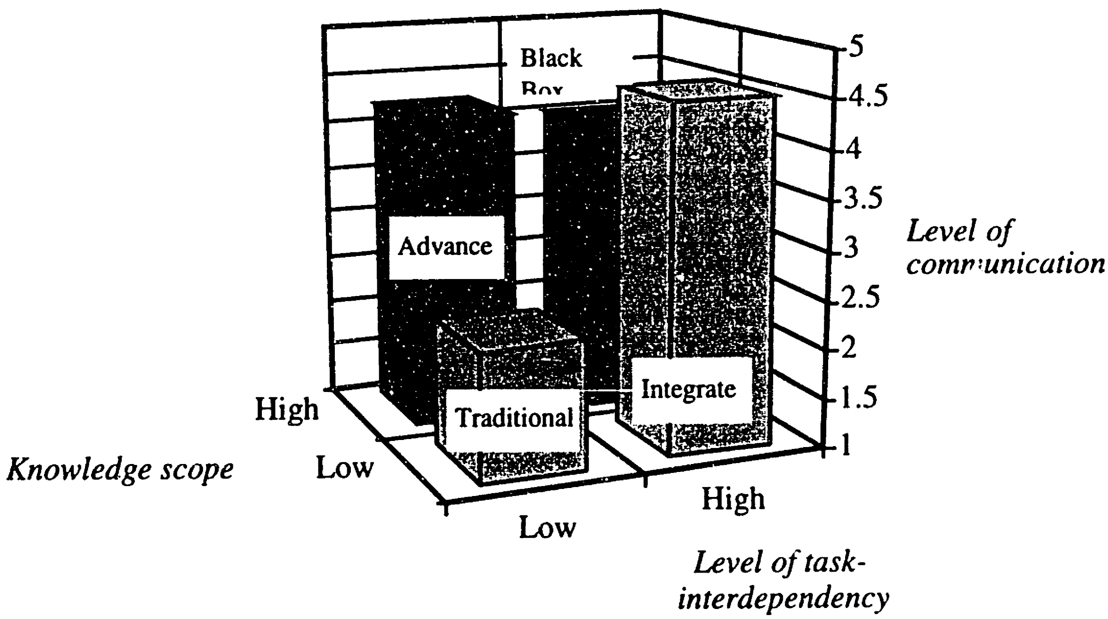


Figure 4. 5 - Level of communication with supplier by task characteristics.

One way to overcome the costs deriving from higher level of communication could be to increase the overlap of the activities between the parties (see figure 4.6). Indeed this seems to be the strategy chosen for the Integrated type of relationships, which show the highest level of overlap (.637). However, considering that the relationship has been activated quite late in time, this effort does not seem to pay. In this case the Level of

Interdependency dimension captures most of the effect, showing how Traditional and Advanced types, by being off the critical path, do not justify investments in overlapping and rather suggest a more sequential approach. This is particularly true for the Traditional type of subcontracting, which show the lowest value among the four. In the Advanced type of relationships the opportunities to overlap are essentially reduced to the joint evaluation of the proposed solutions, similarly to what happens in the Black-Box case, although to a greater extent given their higher level of interdependency.

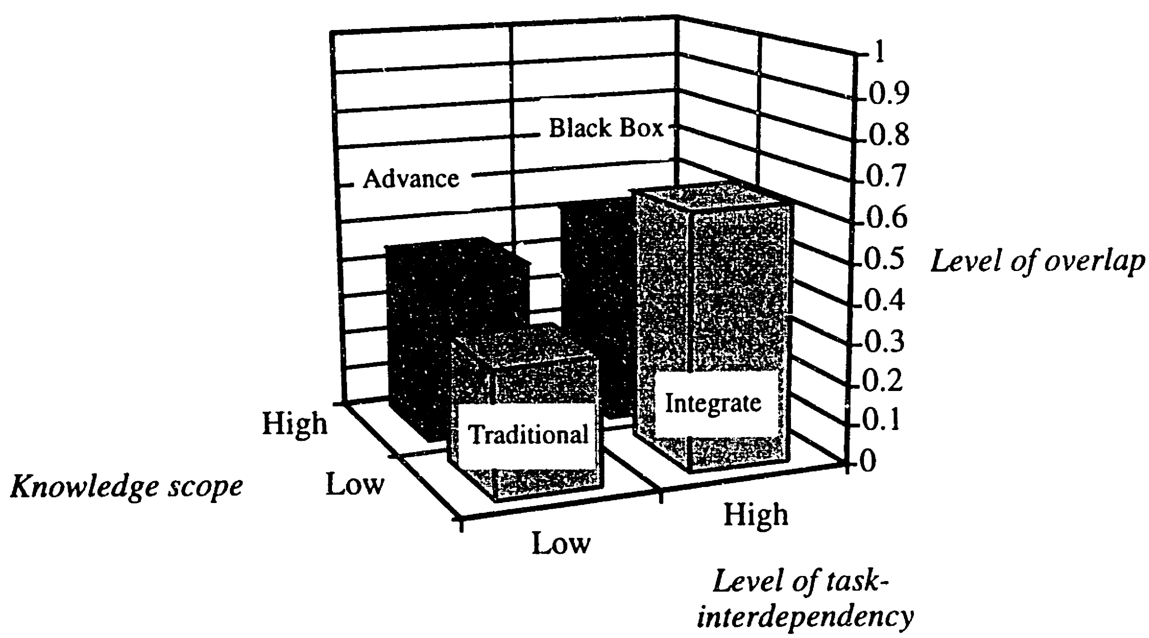


Figure 4. 6 - Level of overlap with supplier by task characteristics.

With this interpretation in mind, the high overlap values showed by Integrated types looks even more as a reactive strategy attempting to overcome some of the difficulties already encountered. Moreover, they also reflects the contemporaneous occurrence in two different sites of problem solving activities moving on two different levels. On the one hand, suppliers are busy trying to come up with reasonable solutions at the functional parameter level, oftentimes struggling with the peculiarity of the requests received in the absence of the needed complete vision of the problem. On the other hand, the manufacturer engineers are closely monitoring the effects of the proposed solutions on the rest of the project, and accordingly readjusting their requests, after likely changes at the concept design level. Although there is overlap, the different knowledge levels at which the separate activities occur generate a sequential effect, which in turn translates into greater inefficiency.

4.6 Conclusions

The research presented in this chapter points to four important theoretical and practical aspects for the management of inter-organizational relationships in the development of innovations. First, it extends the analysis of inter-organizational innovation processes as problem solving activities by determining the role of knowledge characteristics. Second, it develops a link between the type of knowledge being exchanged and the expected outcome. Activating linkages with other economic agents per se is neither good nor bad. Rather, consequences depend upon the content of the tie. Third, it provides a field test of this argument focusing on the relationship as the unit of analysis, rather than inferring its content indirectly by looking at actors' behaviors (Brusco, 1982; Piore and Sabel, 1984; Powell and Brantley, 1992) or attributional properties (Harrigan, 1986; Anderson and Weitz, 1989; Nishiguchi, 1995). Finally, it gives practical insight to operational mechanisms used to structure inter-organizational relations and shows how such mechanisms are central in pursuing different types of goals.

To fully develop these findings, we now need to extend the assessment of the fit between the characteristics of the tie (established between the partners) and the structuring mechanisms (chosen to manage the transaction) on the outcome of the relationship considering the whole relational set in which the actors are embedded. This require a change of perspective. Instead of looking at single relationships, one needs to analyze a group of actors and their entire network of ties, verifying the existence of differences in the relational strategies, their link with characteristics of the relationships established and how and if different choices are reflected in different outcomes. In the following chapters I elaborate this perspective using social network analysis approaches and techniques to model inter-organizational relationships, articulate in relational terms alternative interaction strategies, link them with the characteristics of the tie, and assess the overall network effect on individual actors' outcome.

CHAPTER 5
Inter-organizational relations in new product development: a network approach

5.1 Introduction

The analysis of supplier manufacturer relationships examined in the previous chapter raised three important points. First, it showed that relational outcomes can be quite different. Second, that to understand such differences it is important to focus on the specific characteristics of the activities being partitioned among the actors. Third, that choices among alternative coordination mechanisms are to be examined accordingly, to determine the preferred solution for a given combination of relational characteristics and expected outcome.

The empirical evidence confirmed the conclusions reached in chapter 2 with the quantitative meta-analysis of previous research on inter-organizational relations. Once more the characteristics of the activities performed within the relationships are fundamentally linked to the resulting outcome through the structuring alternative chosen.

These results are derived by theoretically grounding interactions among multiple agents in the information processing perspective of organizational action, with a particular focus on innovation development activities. The actors involved are faced with an incomplete information set with respect to the task at hand, and consider the access to external information sets as a way to overcome their own weaknesses. As a consequence, the characteristics of the information being traded become central in understanding the whole process and its underlying structures.

To completely articulate this perspective it is now necessary to focus on both the actor level implications of the information search process and the consequences for the larger relational set. In particular, to further assess and specify the role of the characteristics of the activities being partitioned as a way to understand relational structures and outcomes, we need to elaborate the transfer process itself in relational terms. This means to go into the black box of transfer flows and examine the role of scale effects (ex. the overall amount of information being transferred) as well as scope effects (ex. the diversity of information sources), the role of direct vs. indirect access to information, and the outcome implications of alternative relational strategies.

The next two chapters approach these issues. This chapter is dedicated to framing the problem in relational terms and testing the consistency of the results obtained previously in a different setting using a different methodology and different data-analytic techniques. The following chapter moves this analysis one step further by examining the link between relational strategies and performance. For the empirical analysis I use in both chapters a unique data set, with complete relational data among 25 distinct organizational units for 173 new product development projects performed during 1994. The data are analyzed using network analysis techniques to model interactions in pure relational terms.

It is important to note how, despite the substantial changes in the research design and data analysis choices, the unit of analysis (a single relation) is consistent with those used in previous chapters. Moreover, the level of analysis itself (a product development project) is also kept constant with respect to the analysis of supplier-manufacturer relations examined in chapter 4. The apparent differences in the techniques and methodologies used should therefore not underscore the continuity of the research plan carried through this dissertation.

The following sections are organized as follows. In section 2 I discuss the notion of innovation as the combination of multiple heuristic search processes, linking it to the information processing view of organizations. Scale, scope, focus and differentiation notions of information transfer are clarified and investigated with respect to the characteristics of the transferred objects. In section 3 I interpret these concepts in relational terms, building on the tools and assumptions of social network analysis. Specific relational constructs are introduced and their relationships with the characteristics of the exchange are postulated, developing a set of testable propositions. Section 4 describes the empirical study designed to test these propositions, discussing the data, the research design and the analytical techniques used. Considering the novelty and peculiarity of the approach, particular emphasis is given to present both a formal definition of the indicators used and their conceptual meaning. Section 5 presents and discusses the results of the analyses and section 6 concludes by exploring their implications with respect to previous findings and the following analysis performed in chapter 6.

5.2 Innovation processes as resource combination activities

In several instances during the previous analyses I recalled the modeling of innovation activities as processes involving information search and elaboration. For any given problem, an actor is faced with an existing amount of physical resources and knowledge on how to use such resources to identify a solution for a given problem. As a first approximation, we can indicate the match between the actor's resource set and the problem to be solved as a direct predictor of the outcome of the process. Actors do not operate in a vacuum though. Whenever the available internal resources are inadequate, they scan the external environment to find the needed complementary resources to be combined to solve the problem.[1] The search occurs not only through predetermined formal channels, but also, and oftentimes more effectively, through informal personal contacts (Granovetter, 1974; von Hippel, 1987; Schrader, 1991). In assessing the outcome of this process, it therefore becomes important to consider the capabilities and opportunities to scan the external environment to gather the additional resources needed.

Previous research emphasized different aspects relevant to approach this issue. First, one important factor is related to the amount of information the actor can gather, the assumption being that the more the better. Cohen and Levin (1990), show how actors engaged in more R&D collaboration were more likely to be innovative, provided that they invested internally on how to profit from external resources. Kogut and colleagues (1995) document how complementarity in the innovation process could be nurtured through external linkages, subsequently increasing barriers to entry for direct competitors. In his

[1] Internal norms can undermine the search by creating high barriers to search for and accept solutions developed outside of the organization, as documented by Katz and Allen (1982) in the context of R&D laboratories.

longitudinal analysis of US biotechnology firms Clarysse (1996) finds that scale constraints can be overcome by investing systematically in external ties, activating several contacts spanning across the whole value chain. To successfully scan the environment, actors need to invest on high levels of transaction (Freeman, 1991). Scale effects therefore emerge as a relevant factor in examining relational activities.

Second, and partly related to the scale factor, actors who access a more varied pool of resources are better off (Arora and Gambardella, 1991; Badaracco, 1991; Ciborra, 1991). In this case, it is not sufficient anymore to engage in high levels of transactions with the external environment, but it is necessary to diversify the sources accessed for several reasons. First of all, by distributing the exchanges among different actors dyadic dependency is limited (Pfeffer and Salancik, 1978; Anderson and Weitz, 1989; Heide and Miner, 1992). Moreover, the more varied the activated set, the lower the chances of overlap among its members, and therefore the lower the redundancy of the established exchange structure (Burt, 1992; Powell and Brantley, 1992). Finally, a wider scope decreases the cohesiveness of the actor's exchange structure, allowing greater freedom of action and choice (Burt, 1992). Consequently, lower pressure to conform and higher acceptance of variance create more favorable conditions to overcome competency traps (March, 1981; Levitt and March, 1988).

In addition to focusing on the resulting flow of resources, however, another important aspect is related to the structural ways through which the process occurs. Underdetermined explanations assume complete freedom in the relational choices and consequences (Alchian and Demsetz, 1972; Williamson, 1985). Ties are sent and received according to the rational choice of individuals. Overdetermined explanations constrain any relational set to the specific environmental conditions in which it occurs (Laumann and

Pappi, 1973; Granovetter, 1985). Actors are limited in their choices by the relational constraints in which they are embedded. While neither of the two positions is completely satisfactory (Cusumano and Takeishi, 1995; Nishiguchi, 1995), their comparison is instrumental to highlight what Granovetter called weak ties (Granovetter, 1973). Exchange occurs not only via direct contacts with other actors usually engaged and activated to complement one's internal deficiencies. On the contrary, the needed resources oftentimes flow indirectly, via normally overlooked channels (Granovetter, 1974).

Research in different settings shows that different structural arrangements are conducive of different results depending on the content of the exchange (Wellman and Wortley, 1990; McAdam and Paulsen, 1993). Indirect influences on individual actions, however, emerge as a function not only of positioning within a relational set, but also of the articulation of relational set. Padget and Ansell (1993), for example, use the concept of multiplexity to show how the activation of different types of relationship (trade, wedding, etc.) were used by Cosimo de' Medici to leverage power and status. Indirect influences among the subjects can therefore be mediated by intermediaries or by multiple contexts of interaction. A closer look at the structural patterns of the relational structure should therefore accompany an analysis of relational size and scope to fully ascertain its implications.

The characteristics of the interaction are at the core of the theoretical explanation and of the empirical evidence produced for all the different aspects of exchange processes. This is particularly true when we focus on innovation activities where, for any given actor, the existing resource set is unlikely to suffice to completely and successfully perform the project. On the one hand, the blurring boundaries between knowledge domains are increasingly requiring the combination of different competencies in many more fields than it used to be in the past (Rosenberg, 1990). On the other hand specific investments are difficult for individual actors to make in different domains due to the presence of scale effects, which oftentimes do not justify allocation of resources when their use might be limited (Henderson and Cockburn, 1992). The more the innovative project requires resources outside the actor's domain, the more external ties become critical and so does their activation and use.

The contemporaneous need to invest in scale and scope emerges as a dilemma, which can be approached by leveraging on inter-organizational relations (Oliver, 1990; Grandori and Soda, 1995). Focusing on the characteristics of the task partitioned among the actors we should be able to anticipate the exchange structure, offering insights on how to approach inter-organization strategies. In its simpler terms, this means that variance in the characteristics of the innovative project should be associated with variance in the different relational aspects (i.e. scale, scope and structural patterns).

Building on information processing models of innovation development, we can identify uncertainty as the fundamental analytical category to distinguish among different tasks (Lawrence and Lorsch, 1967; Thompson, 1967; Galbraith, 1973; Tushman and Anderson, 1986). Among the different definitions proposed, Thompson's (1967) dual notion of uncertainty seems appropriate in this context. He distinguished between uncertainty on the actions to achieve a certain goal and uncertainty on the goal itself.[2] Taken together, these two dimensions are useful to identify how complex is the project observed, and where should the attention be addressed to obtain the expected outcome.

[2] This distinction is implicit in several contributions in the Decision Making tradition (Tversky and Kahneman, 1974) and has been formulated also as a distinction between uncertainty and ambiguity (Schrader et al., 1993).

External relations can therefore be activated to different extents and through different patterns depending on different degrees of complexity.

How can we model the relationship between task complexity and inter-actor relational patterns? Can we expect to observe differences in the scale of the exchange, its scope, and structural patterns at different levels of task complexity? In the following section I introduce some of the concepts developed in social network analysis to answer these questions and identify some theoretical constructs which can be used to define formally a set of testable propositions linking relational structure and task complexity.

5.3 A network approach

Whenever innovation processes are modeled as heuristic search processes (Nelson and Winter, 1982), they involve the search, elaboration and retention of new information to be incorporated in the existing internal information set. New ideas and knowledge are searched around to generate variance in the resource set and create the condition to choose among possible alternatives (Rosenberg, 1990). Higher variance favors a larger choice set, but is more costly to be generated and might not be accepted internally, if providing sources of challenge or replacement of existing routines. Subsequently, some kind of selection mechanism is activated to choose among the possible alternative options. Finally, the chosen option is retained and becomes part of the organization routine set (Winter, 1987).

In such a process, so far the focus has been on individual actors' characteristics, as the explanatory sources of the observed differences in efficiency and effectiveness. However, during this search, each actor becomes embedded in a series of relationships, to gather additional information and access resource sets outside his domain of control.

According to a wider structural perspective, the final outcome of the process is also dependent upon the characteristics of the relational structure in which the actors are embedded.

A social network analysis approach is particularly promising in this sense. Within different domains, from anthropology to mathematical sociology (Scott, 1991), it has been used to describe and model the structure of one or multiple sets of relations among actors, whether individuals (Krackhardt, 1990; Ibarra, 1992), groups of individuals (Breiger, 1974; Allen, 1977; Rogers and Agarwala-Rogers, 1983), or even industries or nations (Breiger, 1981; Burt, 1992). Relations among actors can be used to investigate the overarching network structure as well as to interpret the meaning and role of positions within the network. Similarly, individual actors' characteristics can be used to identify their micro or their macro implications for the overall relationship structure.

For example, Allen (1977) has long been proposing the role of gatekeepers in an R&D organization as fundamental nodes in the relationship structure of the organization. His findings show at the macro level the relevance of that role for the overall integrity of the flows within network structure. At a more micro level, the role characteristics represent the basis for human resource management practices to be implemented at the individual level for the overall structure to function.

Burt (1978) distinguishes two alternative and possibly somehow conflicting approaches within social network analysis: relational approaches and positional approaches. Relational approaches focus on relations among actors and aggregate actors connected through cohesive bonds into "cliques". Positional approaches, instead, focus on the patterns of relations in which individual actors in the network are involved, and aggregates actors with similar patterns. Recent examples of the two different approaches in the analysis of inter-organizational relations include the works of Hagedoorn (1995), where the relational structure of the electronic industry is assessed at several instances in time, and Lomi and colleagues (1994), where individual firms are aggregated in isomorphic blocks according to the amount and type of relationships along their supply chain.

Within relational approaches, the first aspect to be considered is the amount of relational activity occurring within the observed network. Relational structures can be compared both at the overall network level, and at the individual actor level on the basis of the amount of transactions observed. On the one hand, the intensity and the frequency of exchange determine the degree of connectedness among the actors of the network. On the other hand, the level of exchange measured at the individual actor level identifies key individuals in the network. Several concepts have been proposed to operationalize these intuitions (Freeman, 1979), such as degree-centrality (i.e. the extent to which an actor is directly related to the other members of the network), betweenness (i.e. the extent to which an actor controls communication channels by laying in-between other actors in the network) or closeness (i.e. the extent to which an actor has direct access to the exchanges occurring in the network).

Previous research showed that depending on the characteristics of the transferred set, different processes and strategies could be activated. The analysis of R&D projects, for example, has linked the characteristics of the task to the most appropriate organizational solution, both using an actor based perspective (Ancona and Caldwell, 1992), and a relational one (Allen, 1977). In both cases, communication flows and interactions among the problem solvers and other resource owners were deemed essential to complete the tasks at hand. Differences are to be found in the amount and characteristics of the communication patterns as a function of the specificity of the tasks. Katz and Tushman reported a positive and significant correlation between inter-unit communication and project development completion time (1979). Similar results were also obtained by Allen (1970) and Katz and Allen (1985). More innovative projects required higher communication levels and were completed more quickly when the problem solvers occupied some critical position in their relational structure.

Using a network perspective, this means that differences among projects along task characteristics should account for relational differences. In particular, focusing on task complexity, we can expect that more complex projects will require on average higher communication efforts to access a wider set of possible solution and scan a larger amount of information. On the contrary, for less complex projects the problem solver is less likely to depend on external resources for the identification of the solution set. Rather we can assume that the problem solver has a more complete internally developed set of competencies to accomplish her task. Focusing on the level of exchange activity we therefore formulate the following hyopthesis:

H1a: The higher the complexity of the task, the denser the relational structure.

Similar arguments also hold at the individual actor level. Consider for simplicity the extreme case in which any actor relational set is given. There is no chance to enlarge the set, but within it any tie can be activated at any time. The association between task characteristics and relational flows simply states that within the given set the observed relational activity will be higher or lower depending on the characteristics of the task at hand. The relational activity will not only be higher, but also distributed within the network. Relational differences can therefore also be expressed as variation in the intensity and directionality of the activity flows at the level of single actor. This leads to the following hyopthesis:

H1b: The higher the complexity of the task, the higher the relational activity of each individual actor.

Focusing on the exchange levels within the different relational sets limits the attention to the scale of such activities. Indeed the question addressed is how much is exchanged. This alone, however, is not satisfactory to determine the role of task characteristics on relational structure. The very nature of the search process perspective, in fact, implies that a higher level of complexity requires the combination of several different resources, supposed to be distributed among different actors. In addition to observing differences in the "size" of relational activities, we should also be able to detect differences in the "scope" of these activities. With respect to the former, as we just said, the more complex the task the higher the amount of activities actors need to be engaged in. With respect to the latter, the more complex the task, the more differentiated the exchange set. Intuitively, this implies not only an asymmetric distribution of resources among the actors, but also a larger need to access several different types of resources. Consistent with the notion of specialization and fragmentation of knowledge domains, higher levels of task complexity require the combination of multiple resources. Therefore, the scope of the relational activities should be wider.

Network analysis approaches the definition of the scope of relational activities both at the overall network level and at the actor level. At the network level the focus is on the variance in the relational set. The higher the variance, the more distributed the activities, the wider the scope of the exchange. While useful as a first approximation, network-level measures are less effectively capturing relational scope than actor-level ones, usually called Rank or Prestige indexes and based on the analysis of actors' relational sets. Relational scope becomes a function of three elements: (a) the size of each individual relational set, (b) the distribution of the exchanges within such set, and (c) the characteristics of the actors involved in the set. All these elements impact innovative processes. Research on the different roles in innovation processes showed the key role of a large and diversified relational set to effectively scan the environment (Rogers, 1983; Roberts, 1988). The analysis of information-trading activities demonstrated the importance of reputation derived from other relational activities to access valuable resources (Schrader, 1991; Heide and John, 1992). We can therefore link task complexity and the scope of relational activity through the following hyoptheses:

H2a: The higher the complexity of the task, the wider the scope of the relational structure.

H2b: The higher the complexity of the task, the wider the relational scope of each individual actor.

The analysis of relational scope is based on the assumption that information is a perfectly tradable good. Therefore low variance in the relational set determines an inefficient resource allocation by inadequately duplicating the type and sources of information accessed (Burt, 1992). While useful as a first approximation of the composition of the resources involved in the observed exchanges, these assumptions are sensitive to the type of exchange itself. A full analysis of indirect contacts among the actors observed should therefore rely on different tools and approaches. Sub-group analyses are particularly appropriate for this purpose.

In essence, sub-group analysis examine the cohesiveness groups of actors in the overall network.Cohesive sub-groups are considered to be theoretically important for several reasons (Wasserman and Faust, 1994, p.251). First, social forces operate strongly by contact with others belonging to the relevant reference group (McAdam and Paulsen, 1993). Second, exposure to exchanges in the network is frequently mediated by the reference group (Ibarra, 1992). Third, unbalanced cohesion among the members within and outside the reference group is frequently observed (Gerlach, 1992).

If we expect to detect differences in the size and scope of the relational flows depending on the characteristics of the task, we therefore also expect to observe consequences at the structural level of the relations. Consider, for example, the pharmaceutical industry (Gambardella, 1995). In the initial stage of a project, where the goal is to identify several possible compounds for use in animal testing, researchers are scanning intensively information sources inside and outside the organization, to collect ideas, verify intuitions and conduct some preliminary tests. This higher relational intensity is also reflected in the composition and type of the sub-groups involved in the relational flow. Sub-groups are more numerous, i.e. several researchers are connected with many different sources of information, and are also larger in size, i.e. more than one researcher is connected at the same time with several other researchers both in the academia and in the industry. The opportunities to access information are leveraged both via indirect contacts with intermediaries embedded in articulated relational structures, and by interacting with some actors on multiple contexts.

Considering the complexity of the task, we can easily grasp the need for wide and differentiated relational flows connecting a large number of actors to collect and integrate the amount of information needed to perform effectively the required task. Specific indications on the relational structure as a function of the task can be directly derived from a sub-group analysis. Intuitively, for any given set of actors, the higher the number of the sub-groups, the higher the chances of between group interaction via some key actor and the more interconnected the overall relational structure. Similarly, for any given set of actors, the higher the number of members in any of the sub-groups, the higher the chances of co-membership within different groups for any actor and, consequently, the more interconnected the overall relational structure through higher levels of multiplexity. This leads to the following hyoptheses:

H3a: The higher the complexity of the task, the higher the number of sub-groups in the network.

H3b: The higher the complexity of the task, the larger the size of the sub-groups in the network.

5.4 Empirical Analysis

Project level data were collected from an organization focused on basic and applied R&D in the steel industry. For confidentiality reasons I will call this organization ALFA. In 1994 ALFA sales volume was 60 million dollars, with a total of around 400 employees. ALFA was structured in two main sets of units: the administrative set, grouping all the staff functions, and the technical set, grouping all the technical units performing different types of research projects. The technical units in 1994 were structured in six Departments, all separated according to the type of clients served and the technical aspects covered. Each Department was directed by a Department Head, who reported directly to the General Manager. All Departments were in turn articulated in several second level units, which we call for simplicity Functions. In 1994 25 Functions were active. Functions were directly responsible for the execution and management of specific development projects. To perform these projects they could involve other resources which were deemed necessary.

Functions can therefore be seen as similar to independent organizational units within a larger legal entity, like for example the units of a multidivisional firm. While homogeneous with respect to the contractual coordination mechanisms to govern their transactions, they are free to choose among different procedural coordination mechanisms. Relationships among functions can therefore be used to model inter-organizational relations, holding contractual coordination constant. This simplification, which at first sight might seem inappropriate, reflects some real instances, where the limits of the contractual coordination mechanisms make it reasonable to consider them as a constant for all the actors observed. One example in this sense is the analysis reported in chapter 4, where the differentiation on the contractual side to govern supplier-manufacturer relations was almost absent, because of local practices and deficiencies in the supporting institutional environment.

5.4.1 Data structure

I collected data on each project recorded as active during the 1994 calendar year.[3] In total, 173 projects were under development during 1994. This is the population used in the analysis. For each project, I identified the Function responsible and the total number of man hours assigned to the project, partitioned into the total number of man hours in the lead-unit and those in the other units involved. The resulting relational data use the number of hours bought (or sold) by a unit from (or to) another to measure the existence of a tie and express its strength, distinguishing between ties received and sent. By cumulating this information for each project and each second level unit, I generated one asymmetrical squared adjacency matrix at the Function level (n=25), representing the project development relational activities among the Functions.

Each cell of the data-matrix reports the total amount of hours worked by the row unit for projects lead by the column unit.[4] Diagonal elements represent the total amount of hours worked internally by the unit on projects it directly was responsible for in the observed time. Technically, data are valued and directed. They are valued, since the relation between the units is not expressed as either present or absent, but is measured in a metric which is consistent by level, time and type of aggregation. They are also directed, since sending and receiving units can be distinguished.

To control for two possibly serious threats to internal validity, these data, using budget and billed hours, were computed at three different times: the beginning of the year

[3] Projects included: (a) projects started before 1994 and planned to be finished later than 1994, (b) projects started before 1994 and planned to be finished during 1994, (c) projects started in 1994 and planned to be finished later than 1994, and (d) projects started in 1994 and planned to be finished during 1994.
[4] The usual coding procedure within network analysis studies is reversed, with row data indicating the relations from a unit to another. This is also reflected in the way data are analyzed by all the available software packages. Before any analysis I therefore transposed the original matrices.

(as planned by the budget), in the middle of the year (both for budget and billed hours) and at the end of the year (as resulting from the final billing). Since the famous Hawthorne studies (Roethislberger and Dickson, 1939), the coexistence of structure-determined interactions and action-determined ones has been a strongly debated issue, both theoretically (Weick, 1979) and empirically (Barley, 1986; Barley, 1990). On the one hand, we are provided with empirical tests of discrepancies between planned and observed structures based on relational analysis. On the other hand, the theoretical underpinnings of such differences are varied and sometimes contradictory.

We could therefore at best only expect to observe differences between planned and observed data, but not to firmly establish why they might emerge. Moreover, we cannot establish the level at which we could expect such differences to emerge. Should it be at the level of amount of relational flows? Or in the directional patterns of such flows? Or rather at the relational structure level in terms of sub-groups and their composition? Although no firm expectation about the answers to give to these questions can be formulated, possible differences between planned and observed relational data should be controlled for in the analysis. To do so, I consider both planned data (budget) and observed data (billed).

The second threat to internal validity which might be encountered depends on the type of data used to measure relational activities. Accounting based measures are prone to several potential biases depending on their design, implementation and use by the organization. This is particularly true for the comparison of beginning of the year budgets and end of the year data, where readjustments in flows to gain an overall balance are typical. For example, the researchers of Unit A represent a fixed cost to be expensed anyway at the end of the year. Their underutilization within projects S and J might then be nominally compensated in the final accounts by reallocating them to projects R and W. To limit the effect of these practices, I therefore use the middle of the year data.

Further information was also collected at the project level. More precisely, for each project I built a demographic record including information on: (a) Name of the project, (b) Code of the project (used for internal identification purposes), (c) Project type (R&D, Technological Assistance and Service Maintenance), (d) Starting date, (e) Ending date (planned), (f) Total cost of project, (g) 1994 budget for the project, (h) Project leader and unit he/she belongs to. Most of this information will be used in the following chapter. For the purpose of the analysis conducted in this chapter, however, it is important to further discuss the coding procedure followed to identify the different project types.

Within ALFA, projects are partitioned into three sets according to their degree of innovativeness. The first set, called internally "R&D projects", groups all the projects with a planned duration of 5 years on average, usually partly financed by the European Union through special funds dedicated to industrial research, and performed jointly with other industrial and non industrial partners. Projects in this category were for example aimed at the definition of radically new blast furnace technology, the reconfiguration of casting processes, the production of colored steel alloys and the like. Not only is the time span longer in this group of projects, but also the range of applicability of their results is wider and partitioned among a diversified set of subjects.

Projects in the second set, called internally "Technological Assistance" are shorter in duration, and usually more applied in their nature and expected results. Within this group we normally find projects addressing specific implementation needs of a well identified client. Frequently, these projects are follow up of "R&D projects" commissioned by one of the previous partners. Typical targets of "Technological Assistance" projects are cost reduction or quality improvement plans in existing processes. While still requiring a strong theoretical background, the projects are narrower in scope and of shorter duration (between 1 and 3 years).

Finally, the third set, called internally "Service Maintenance", groups all the projects commissioned by one specific client to sub-contract technological assistance at the plant level. Typical activities include laboratory testing, process consulting and quality certification. The projects are clearly much shorter in duration, usually corresponding either to a specific contract for the supply of a clearly identified service, or for general assistance throughout a whole calendar year.

I use this internal classification scheme to partition the whole set of projects according to their level of complexity. A decreasing level of complexity is assumed in moving from "R&D projects" to "Technological Assistance" projects to "Service Maintenance" projects. While apparently weak on construct validity, this operationalization responds to some fundamental premises underlying the complexity concept. First of all, the different time horizons attached to each subset provides a first approximation of the amount of problem solving activities required. Yet, one might argue that the longer time span characterizing certain projects could be merely a function of its overall size and the limited amount of resources available. Secondly, the nature of the task itself is inferred indirectly, assuming that the partitioning criteria adopted within ALFA either explicitly or implicitly use the notions of complexity and that such notion corresponds to the one here presented. Finally, while I rely upon a group partitioning criteria, I do not consider any within group differences.

While the last point will be addressed in the following chapter, after several in depth discussions and interviews with ALFA personnel at different levels of responsibility I feel confident in discarding the other two possible threats to the complexity construct validity. Differences in time span are not a partitioning criteria, but simply the result from a comparison of the different groups. On the contrary, they signal significant inter-project differences related to the type of tasks performed within the projects. While not explicitly made, the difference in the type of tasks performed is indeed at the basis of the internal partitioning in the three groups, which therefore represent a reliable operationalization of inter-project task-related differences.

For the following analysis, I therefore split each one of the two original adjacency matrices (planned vs. observed exchanges) for the middle of the year in three matrices, using project type as partitioning criterion. The distinction among types of projects is instrumental in investigating the differences in the relational structure as a function of task characteristics. Moreover, by performing the analysis on both the planned and the observed structure, I control for the possible presence of spurious variance in the system. The final data structure used in the analysis is therefore made of a set of six adjacencies matrices at the Function level, articulated by task characteristics and planned vs. observed relationships.

While extremely rich, this type of data set is particularly challenging to examine computationally. Available algorithms to elaborate relational data are still rather incomplete for the simultaneous examination of valued and directional data (Wasserman and Galaskiewics, 1994). To limit any computational problem and still retain the richness of the data, I decided to recode the valued matrices into binary matrices, preserving the directionality of the relationship. The main limitation resulting from this choice is the impossibility to discriminate among the different relations on the basis of their strength. This could represent a problem, should I need to distinguish among specific actors on this basis. However, since the focus is on the aggregate set, the dychotomization of the original valued data represent a valuable data compression choice which would not limit significantly the analysis.[5]

The cut-off criterion used is the value of the relation with respect to the total amount of activities performed by the actor. Considering the projects observed, the 5% threshold was deemed appropriate Substantially, this means that any exchange lower than 5% of the total resources managed by a unit was ignored. Technically, for each of the valued matrices ($\mathbf{V}^{t,s}$) a new dichotomized matrix ($\mathbf{D}^{t,s}$) was generated where:

$$\forall i,j \quad d_{i,j}^{t,s} = \begin{cases} = 1, \text{if } \dfrac{v_{i,j}^{t,s}}{\sum_j v_{i,j}^{t,s}} \geq .05 \\ = 0, \text{otherwise} \end{cases} \qquad (1)$$

5.4.2 Constructs operationalization

The next step in the analysis is to operationalize the theoretical framework presented in figure 5.1. The framework assesses the role of task complexity in determining the intensity (i.e. relational size), the patterns in the flow of activities (i.e. relational scope), and the internal pattern of such activities (i.e. relational structure) among the actors involved in the process. To test these relations, I use several different concepts developed within social network analysis and based on a relational approach. In the following paragraphs I explain how I operationalized these constructs.

[5] I am in debt to Brian Uzzi for pointing out this issue to me.

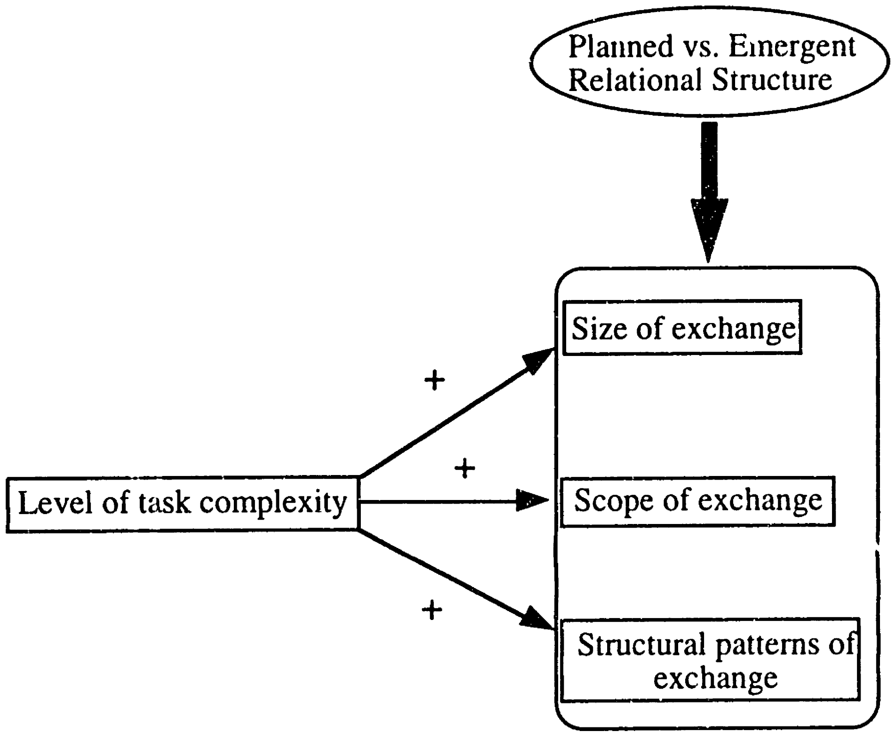


Figure 5.1 - The hypothesized relationships

5.4.2.1 Relational size

To analyze the level of relational intensity I first determine the density of each network. The density of a network is a first approximation for the amount of contacts among the members of the network, and is expressed as the ratio between the number of contacts observed and the number of contacts theoretically possible (Scott, 1991). The density index varies between 0 and 1. The closer to 1, the more interconnected the network. This is an overall index applicable to the whole network and sensitive to its size. While useful to obtain a first cut of the data, it underscores inter-actor differences.

To move at the level of individual actors for analyzing their relational intensity, I use the concept of actor's centrality as a measure of the exchange between each actor of the network and all the others. Within directional networks, Nieminen (1974) proposed a centrality index distinguishing relations <u>from</u> and <u>to</u> each individual actor, building on the notion of in-degrees and out-degrees. Formally, for any member of the $\mathbf{D}^{t,s}$ adjacency matrix:

Nieminen index of in-degree centrality, $$C^{I}_{i,j}(\mathbf{D}^{t,s}) = \sum_{j} d^{t,s}_{i,j} \quad (2)$$

Nieminen index of out-degree centrality, $$C^{O}_{i,j}(\mathbf{D}^{t,s}) = \sum_{i} d^{t,s}_{i,j} \quad (3)$$

By computing the Nieminen indexes for each member of each network I obtain a set of vectors, reporting information on the in-degree and out-degree centrality levels of each actor. I use such vectors to test for a task effect in the density and intensity of relational activities, controlling for a planned vs. emergent relational structure effect. To complement these indexes, based on the binary matrices obtained from the original data structure as described before, I also use the original matrices to calculate the amount of subcontracted work for each unit, for each level of task complexity. This measure is helpful in making the connection between the results of the formal analysis based on the centrality indexes and its managerial implications.

<u>5.4.2.2 Relational Scope</u>

Within directional relations we can distinguish by definition between relations sent and received. These differences are somehow lost when focusing on measures of centrality, which are mainly concerned with an overall assessment of the volume of relations any actor is involved in. In several contexts, however, focusing on the relations received provides additional insights about individual actor's positioning within the network and the structure of the network itself. It moves from the simple analysis of the size of the exchange towards a characterization of its scope.

The cruder measure which can be used is the indegree of each actor, which informs us on how many actors send information to the one observed. This measure, however, is based on the assumption that all actors areequivalent. In addition to that, by focusing only on adjacent actors, it undervalues the importance of indirect influence. To overcome these weaknesses, I use two strategies to (a) capture the scope of each actor's relational domain, and (b) weight the observed relational domains depending on the type of actors included.

Technically, the first index falls in the Proximity Prestige class and is calculated as follows (Lin, 1976, cited in Wasserman, 1994, p. 203):

$$P_p(d_i^{t,s}) = \frac{I_i/(n-1)}{\sum_i g(d_i^{t,s}, d_j^{t,s}) \Big/ I_i} \qquad (4)$$

where I_i is the actor's Influence Domain focusing on the relations received, i.e. all the actors who directly or indirectly send a tie to actor i; N-1 is the maximum possible size of any actor's Influence Domain, i.e. the whole network; and g(*) is the geodesic distance between actor i and actor j in i's Influence Domain. The numerator is therefore a weighted measure of the size of an actor's Influence Domain. The denominator expresses the average distance between actor i and all the actors in his Influence Domain.

Conceptually, the index considers simultaneously how large is each actor's senders group and how far he is from his senders. The size of the senders set allows us to consider the number of relations activated. The distance from the senders weights the received ties with respect to their closeness. The index varies between 0 (no actor sends any tie to i) and 1 (all actors send a tie to i). The higher the index, the higher the actor's prestige.

The second type of index, usually called Status or Rank prestige (Wasserman and Faust, 1994, p. 205), compares actors' influence domains on the basis of their composition. What matters is therefore less the size and scope of the influence domain, but rather the characteristics of the actors included in such domain. The denomination of this index is derived from its application to the analysis of power distribution among different actors where power is derived by being connected to powerful actors. In this analysis, the intuition is that for a distributed relational structure to occur, there should be higher variance in the status distribution among the actors observed. A concentrated structure, on the contrary, implies a predominant role of few actors. This index can therefore be used in the analysis as another measure of the scope of the relational activity. Technically, the index requires the solution of a set of simultaneous equations like the following:

$$P_r(d_i^{t,s}) = x_{1,i} P_r(d_1^{t,s}) + x_{2,i} P_r(d_2^{t,s}) + \ldots\ldots + x_{n,i} P_r(d_n^{t,s}) \qquad (5)$$

where the prestige of any actor is a weighted measure of the prestige of the actors in her Influence Domain. To solve this system of n equations, for any given matrix $\mathbf{D}^{t,s}$, the Status Prestige index for each actor i is calculated as in (6), where the parameter α is required to obtain a non trivial solution. Following Bonacich (1972), I compute α as the inverse of the largest eigenvalue derived from a factor analysis performed on $\mathbf{D}^{t,s}$. Finally, since this procedure ignores directionality, I perform it focusing on relations received to be consistent with the approach followed for the Proximity Prestige index.[6]

$$P_r(d_i^{t,s}) = \alpha \sum_j \beta_{i,j} P_r(d_j^{t,s}) \tag{6}$$

5.4.2.3 Sub-group structure

To perform the sub-group analysis I use the concept of clans. Formally, a clan is a subset of nodes for which the geodesic distance is not greater than a predetermined value n for paths within the subset. The intuition behind a clan is to identify subsets of actors which are either directly connected between them, or connected via a limited number of intermediaries who are in turn members of the same subset.

Looking at clans within a network provides additional information on its substructure. The higher the number of clans for any given n (i.e. the maximum distance between any two members of the clan), the more distributed the exchange activity within the network. The same is true with respect to the size of the clans. The higher the number of the members within each clan, the more connected the network. For a given network size, however, clan size and numerosity are related. The higher the number of clans and the larger their size, the higher the chances of overlapping contacts among the members in the network. An analysis of the number and size of clans in the network therefore moves at the third level of the analysis of relational activities, complementing the results about exchange scale and scope by providing evidence for the structural patterns of the exchange.

[6] Technically this means: (1) transform the original asymmetric $\mathbf{D}^{t,s}$ in lower triangular (i.e. only ties received are retained), and then (2) run the analysis on the transformed matrices.

Since the data to be analyzed are directional, we can choose among different notions of connectedness to identify the actors. Weak connectedness simply requires the actors to be reachable. Unilateral connectedness specifies the direction through which the actors are connected (ex. from i to j <u>or</u> vice versa). Strong connectedness requires reciprocity (ex. from i to j <u>and</u> vice versa). Recursive connectedness extends reciprocity to also include the intermediaries involved (ex. from i sends information to j, via k, <u>and</u> j sends information to i via k as well).

The notion of weak connectedness is particularly appealing to model structural exchange incorporating spill-over effects and taking into consideration indirect contacts. Intuitively, it implies that actors benefit from relational exchange both directly and indirectly within cohesive subgroups, even through unplanned contacts. By working with B, A might find out about C and decide to activate the relationship or benefit indirectly from a spillover deriving from B and C interaction. For the purpose of this analysis, I therefore use the weak connectedness requirement and identify n-clans as those sub-graphs in which all actors are connected by a semi-path of length n for any semi-path within the subgroup.

<u>5.4.2.4 Planned vs. emergent relational activity</u>

To control for possible differences between the planned exchange structure and the observed one on its size, scope and structural patterns, I compare the budget data with the billed ones. In any analysis, therefore, I include three effects: a task effect, a planned vs. observed effect and an interaction effect. The latter, in particular, will be important to assess the internal validity of the framework, as it will verify the sensitivity of a task-based comparison of relational activities to the type of data used.

While appropriate for the scale and scope comparison, this approach falls short of accounting for differences in the structural patterns. For this purpose I use the QAP-correlation procedure offered by UCINET IV (Borgatti et al., 1992, p. 135). The procedure compares a structure matrix with an observed matrix by correlating the two. It also offers a non-parametric estimate of the robustness of the results using a randomized iterative procedure to build a distribution of correlation coefficients between the two matrices.

Any structure matrix, by definition, is a relational representation of the theoretical structure of a certain set of actors. Usually, the structure matrix is not available, and the researcher needs to use her theoretical underpinnings to build one and use it against the data (Di Maggio, 1986). In this case, however, I can numerically derive the structure matrix from part of the data, using the adjacency matrices reporting budget data. Budget data, in fact, represent the rational planning of relational activities, i.e. the planned structure for that group of actors in the span of time observed. Similarly, I can identify the data matrix by focusing on billed data.

I use co-membership matrices derived from the clan analysis for this purpose. In such matrices diagonal elements indicate the number of n-clans in which actor $a_{i,i}$ is present, and off-diagonal elements the number of n-clans in which actors $a_{i,j}$ and $a_{j,i}$ are present together. Co-membership matrices therefore include information not only on the flows, but also on the structural patterns of such flows within a network. For each type of task, I compare a structure matrix (the n-clan co-membership matrix based on budget data) with a data matrix (the n-clan co-membership matrix based on billed data) using the QAP-correlation procedure. Structural differences will emerge if the compared matrices are weakly or negatively correlated.

Table 5.1 - The variables used in the analysis: a summary

Theoretical construct	Operationalization	Conceptual meaning	Calculations
Scale of exchange			
	Indegree	The volume of exchange activities involving the <u>transfer</u> of resources <u>to</u> other actors.	$C^{I}_{i,j}(\mathbf{D}^{t,s}) = \sum_j d^{t,s}_{i,j}$
	Outdegree	The volume of exchange activities involving the <u>receipt</u> of resources <u>from</u> other actors.	$C^{O}_{i,j}(\mathbf{D}^{t,s}) = \sum_i d^{t,s}_{i,j}$
	Proportion of work contracted out	The dependency on other actors for the completion of the project	$\frac{\text{amount of work contracted out}}{\text{total work}}$
Scope of exchange	Proximity prestige	The extent to which each actor relational set is wide and characterized by strong ties	$P_p(d^{t,s}_i) = \frac{I_i/(n-1)}{\sum_i g(d^{t,s}_i, d^{t,s}_j) / I_i}$
	Status/Rank prestige	An evaluation of an actor's relational set as a function of the characteristics of the relational sets of the actors included in his set	$P_r(d^{t,s}_i) = \alpha \sum_j \beta_{i,j} P_r(d^{t,s}_j)$
Structural patterns of exchange	Clan sub-structure	The number, size and overlap of cohesive subgroups in the overall relational set	Number and size of 2-clans and 3-clans

Notes:
- $d_{i,j}$, value of row i, column j of the adjacency matrix D;
- $g(d_i, d_j)$, geodesic distance between actor i and actor j, i.e. the shortest path between the two;
- I_i, influence domain to actor i - i.e. the number of actors who can reach actor i.

See Wasserman and Faust, 1994, ch. 4-5.

5.5 Results

The elaboration of the data was directed to the detection of a task effect on relational size, scope and structural patterns. Table 5.1 summarizes the empirical indicators used. As a first step in the analysis, I computed the density index for the three levels of task complexity. While generally low in real terms, the pattern observed confirms the expected higher level of density for relational networks involving more complex projects. Focusing on the observed structure by using billed data, the density of R&D projects is .06, while the density of Technical Assistance projects is .04 and the density of Service projects is .02. The pattern doesn't change significantly when focusing on the planned structure instead, by using budget data. While the difference between R&D and Technological Assistance projects is not detected with budget data, as they show equal values (.05) for the density index, Service projects continue to be characterized by a more disconnected structure (density index = .01).

These observations at the overall network structure are consistent when I move to the analysis of the volume of the exchange flows, switching the attention to the different indicators of relational scale. Both with respect to the amount of relations sent (outdegree) and received (indegree), higher levels of task complexity are associated with higher levels of relational intensity (see table 5.2). Results are statistically significant (see table 5.3), even after controlling for possible biases deriving from the use of a planned rather than an observed relational set, and provide empirical support to Hypotheses 1a and 1b. We observe a strong role of the content of the exchange in determining the amount of relational activities. The robustness of the results even after controlling for the possible "duality effect", trying to capture possible inconsistencies between planned and observed relational structures, offers some puzzling evidence to the debate on this issue. Yet, consistently with the nature of the research design, I should be cautious not to make any specific claim about the control variable.

The managerial implications of these results are immediately evident when we use more typical measures of the amount of transactions planned and observed. In particular, if we focus on the proportion of work contracted out relative to the total amount of work for which the single functions are responsible I obtain the same results. For R&D projects, on average each of the active Functions contracts out a higher proportion of work (32%) than for Technological Assistance projects (23%) and for Service Maintenance projects (8%). The lower the level of task complexity, the lower the need to shop around for complementary competencies and knowledge. A move along the task complexity domain determines the extent to which the single functions are more or less able to perform the work autonomously or not, and the corresponding varying degree of coordination required.

Table 5.2 - Relational size: mean values.

		Level of task complexity		
Dependent variable	Type of structure analyzed	High (n=50)	Medium (n=50)	Low (n=50)
Indegree: relations received	Planned (n=75)	1.22	1.16	0.20
	Observed (n=75)	1.36	0.92	0.40
Outdegree: relations sent	Planned (n=75)	1.28	1.16	0.20
	Observed (n=75)	1.36	0.92	0.40
Proportion of work contracted out	Planned (n=75)	32%	23%	8%
	Observed (n=75)	30%	24%	13%

Table 5.3 - Relational size: Analysis of variance.

Dependent Variable	Effect	SS	df	MS	F-value	p-value
Indegree: relations received	Level of task complexity	27.77	2	13.89	12.34	<.001
	Planned vs. observed structure	.01	1	.01	.01	n.s.
	Interaction	1.30	2	.65	.57	n.s.
	Error	162.00	144	1.12		
Outdegree: relations sent	Level of task complexity	27.77	2	13.89	10.00	<.001
	Planned vs. observed structure	.01	1	.01	.01	n.s.
	Interaction	1.29	2	.64	.47	n.s.
	Error	200.00	144	1.39		
Proportion of work contracted out	Level of task complexity	1.08	2	.54	6.94	<.001
	Planned vs. observed structure	.01	1	.01	.10	n.s.
	Interaction	.03	2	.01	.19	n.s.
	Error	11.24	144	.08		

This pattern of association between task and relational characteristics emerges as a key element to consider for innovative processes, even more when we move at the relational scope level. First of ail, when focusing on the analysis of Proximity Prestige indexes we found preliminary support for Propositions 2a and 2b. The higher the level of task complexity, the wider the relational set of the actors observed and the stronger on average the tie with the actors in this set. This is true both at the overall network level and at the individual actor level. Controlling for a planned vs. observed relational structure effect, when performing R&D projects the Functions are characterized on average by higher values for the Proximity Prestige Index (.08), than when performing Technological

Assistance projects (.06) or Service Maintenance projects (.018). These differences are statistically significant (p<.001), as reported in table 5.4.

Table 5.4 - Relational scope: Analysis of variance.

Dependent Variable	Effect	SS	df	MS	F-value	p-value
Proximity Prestige index	Level of task complexity	.12	2	.058	16.07	<.001
	Planned vs. observed structure	.01	1	.01	.01	n.s.
	Interaction	.01	2	.01	.57	n.s.
	Error	.52	144	.01		
Numerator:	Level of task complexity	.51	2	.26	15.47	<.001
	Planned vs. observed structure	.01	1	.01	.18	n.s.
	Interaction	.07	2	.03	2.01	n.s.
	Error	2.40	144	.02		
Denominator:	Level of task complexity	27.94	2	13.97	17.27	<.001
	Planned vs. observed structure	.08	1	.08	.09	n.s.
	Interaction	2.82	2	1.41	1.74	n.s.
	Error	116.46	144	.81		

Decomposing the index and distinguishing its numerator and its denominator further qualifies these results with respect to their organizational implications. The numerator expresses a measure of the size of the relational set of each actor, while the denominator captures the average strength of the ties within the set, measured on how close the actors are. Moving across the different levels of task complexity we notice how Functions tend to rely on larger sets of actors for more complex tasks (see table 5.5).

Whenever performing R&D projects, the average Function relational set is 15% of the overall network, thus including about 4 other Functions. Within this type of projects, the actors in the set can be reached either directly or through at most one intermediary (Proximity Prestige Index denominator > 1). Whenever performing Technological Assistance projects, the activated relational set is smaller in size, about 3 actors, and more compact, as all the actors in the set can be reached directly (Proximity Prestige Index denominator < 1). This compactness of the activated relation set characterizes also the relational activity in the Service Maintenance projects. In addition to that, however, the size of the relational set is sensibly lower (only 1 actor on average), moving towards dyadic structures. Results are statistically robust even after controlling for planned vs. observed relational structure effects (see table 5.4), despite some apparent numerical discrepancies between budget and billed data (see table 5.5).

Table 5.5 - Relational scope: mean values.

Dependent variable	Type of structure analyzed	Level of task complexity High (n=50)	Medium (n=50)	Low (n=50)
Proximity Prestige index	Planned (n=75)	.07	.07	.01
	Observed (n=75)	.08	.06	.02
Numerator: % of the actors in the Influence Domain	Planned (n=75)	12%	18%	1%
	Observed (n=75)	15%	11%	2%
Denominator: average distance from the actors in the Influence Domain	Planned (n=75)	1.15	1.22	.12
	Observed (n=75)	1.27	.79	.30

Continuing to focus on relational scope, I computed Rank Prestige indexes for each level of task complexity using the relations sent, both for budget and billed data. Absolute

Rank Prestige values, however, are difficult to compare between networks because of the scaling bias introduced by the algebraic manipulation used to compute the values, which is sensitive to the size of the eigenvalue chosen to initiate the iteration (Borgatti et al., 1992; Wasserman and Faust, 1994). Before analyzing the results, I therefore normalized the values obtained, dividing each actor's score for the highest value within the group (ex. high level of task complexity and billed data).

The normalizing criterion employed is particularly helpful to detect asymmetric distribution in the Rank Prestige among the actors, which was postulated to be associated to different levels of task complexity. Conceptually, the distribution of the normalized indexes measures the extent to which only few actors score high on Rank Prestige, or rather the relational structure is characterized by a wider distribution of indirect contacts. The inspection of the results reported in figure 5.2 provides further support for hypotheses 2a and 2b and offers some interesting insights.

First, the frequency distribution is clearly more skewed to the right when we move from R&D projects to Technological Assistance and Service Maintenance ones. The higher is the level of task complexity, the larger are the number of actors scoring high on Rank Prestige indexes and the more distributed the indirect influence structure within the observed networks. Second, the pattern is progressively accentuated, with projects low on task complexity characterized by a bimodal distribution with only 1 or 2 actors scoring high on Rank Prestige and all the others either completely disconnected or fairly limited in their relational scope. Third, comparing the results presented in figures 5.2 and 5.3, I find consistent patterns between budget and billed data.

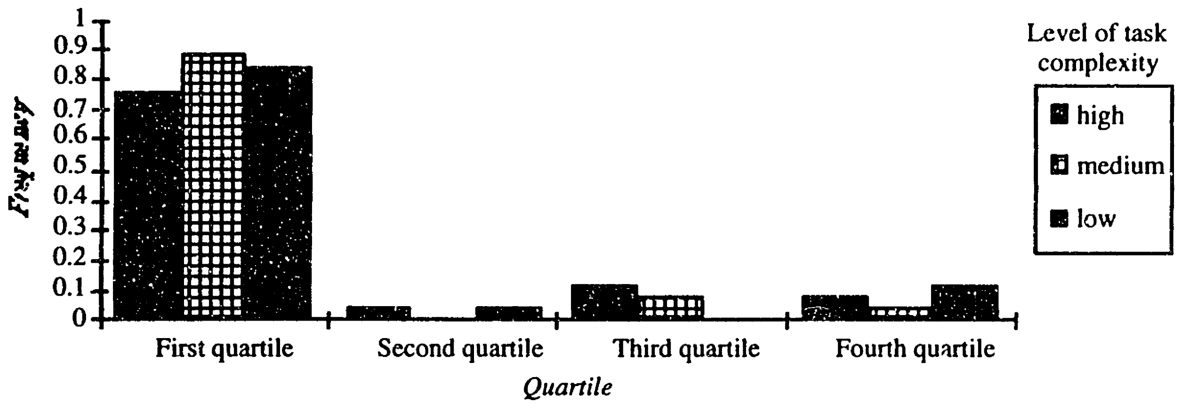


Figure 5.2 - Frequency distribution of rank prestige indexes normalized by the respective maximum value: billed data.

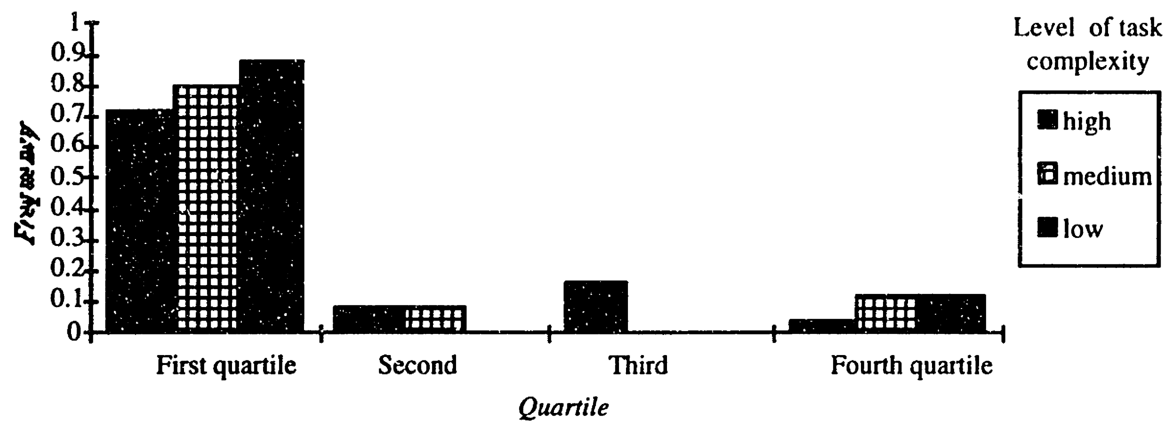


Figure 5.3 - Frequency distribution of rank prestige indexes normalized by the respective maximum value: budget data.

After examining relational size and scope, the next step was to analyze the structural patterns of relational exchange and their association with the type of task performed through the relationships. A cohesive sub-group analysis using n-clans was therefore conducted on the different adjacency matrices, focusing on 2-clans and 3-clans. Numerically, it has been shown that clans with diameter greater than 3 are not meaningful (Borgatti et al., 1992, p. 98; Wasserman and Faust, 1994, p. 260). Substantially, the comparison of two different sub-group analyses based on different, but consistent, inclusion criteria is appropriate to identify stability in the observed patterns.

Figure 5.4 reports the number and size of 2-clans distinguishing among R&D, Technical Assistance and Service Maintenance projects, using the concept of weak-connectedness to determine the sub-groups. What matters is therefore not the directionality of the tie, but rather its presence or absence. Conceptually, this is consistent with the idea that on a structural level, to examine the opportunities to access outside resources, it is relevant to reveal the existence of a contact, rather than focusing on who initiated such contact. Data show support for hypotheses 3a and 3b. The higher the level of task complexity, the larger the average size of each clan and the larger the number of clans in each network.

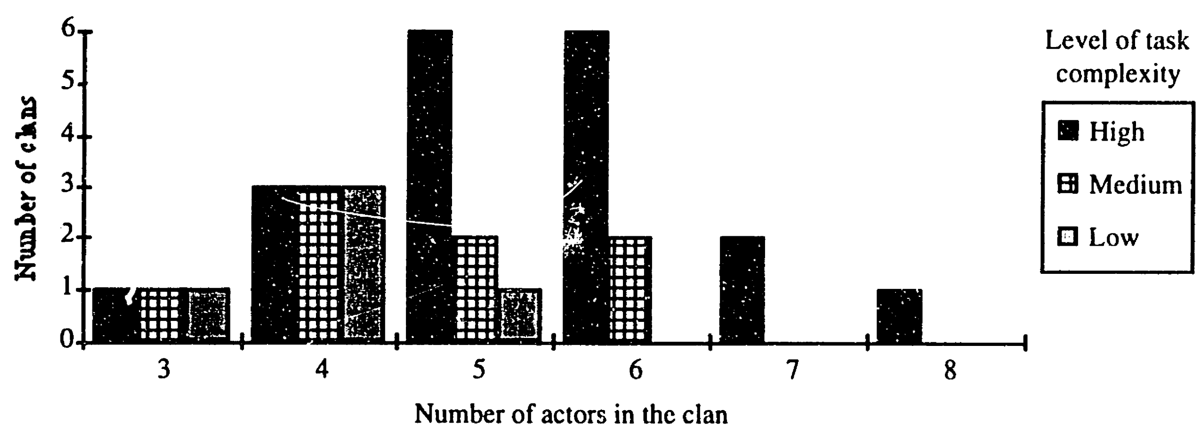


Figure 5.4 - Number and size of 2-clans by level of task complexity

When actors are clustered on the basis of their common membership to different sub-groups, distinguishing by level of task complexity, the combined effect of this distribution emerges more clearly (see figure 5.5). The higher the level of task complexity, the larger the number of actors interconnected through their participation to separate groups. At the same time, though, there is a high degree of overlap among the groups as they share several common members. Exchange opportunities therefore arise by interacting within different contexts.

High task complexity:
R&D Projects

```
      Actor | 1 2 2     1 2 2       1       1 1 1 1 1   1 1 2 2
Level       | 1 1 3 4 8 9 2 4 1 2 6 3 3 5 7 2 4 5 6 7 9 0 8 0 5
------------+--------------------------------------------------
    6       | . . . . . . . . . . . . . . . . . . XXXXXXX . . .
    5       | . . . . . . . . . . . . . XXXXXXXXXXXXXXXXXXXXX .
    4       | . . . . . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXX .
    3       | . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX .
    2       | . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    1       | . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    0       | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Medium task complexity:
Technological Assistance
Projects

```
      Actor |     1 1 1 2 2         1 1 1 1 2     1 1 2 1 2   2
Level       | 4 7 1 4 8 0 3 1 2 5 8 2 3 5 7 1 3 9 0 9 4 6 2 6 5
------------+--------------------------------------------------
    4       | . . . . . . . . . . . . . . . . . . . . . . XXX .
    3       | . . . . . . . . . . . . . . . . . . . . . XXXXXXX
    2       | . . . . . . . . . . . . . . . . XXXXXXXXXXXXXXXXX
    1       | . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
    0       | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Low task complexity:
Service Maintenance
Projects

```
      Actor |             1     1 1 1   1 1 1 1 1 1 2 2 2 2 2 2
Level       | 1 2 3 4 7 9 2 5 8 0 1 3 6 4 5 6 7 8 9 0 1 2 3 4 5
------------+--------------------------------------------------
    3       | . . . . . . . . . . . . XXX . . . . . . . . . . .
    2       | . . . . . . . . XXXXXXXXXXX . . . . . . . . . . .
    1       | . . . . . . . XXXXXXXXXXXXXXXXX . . . . . . . . .
    0       | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Figure 5.5 - Functions clustered by joint membership in 2-clans at different levels of task complexity.

The subgroup structure analysis thus reveals another important relational dimension associated with the level of task complexity. What matters is not only how many ties are activated with other actors (relational size), or how articulated is any given individual relational set (relational scope), but also how extended are the opportunities of exchange in different contexts. Data show clearly that these opportunities are higher and more widespread within the network, the higher the level of task complexity of the joint work.

This is a formal representation of how variance in the search process is related not only to the activated resources, but also to the context in which the exchange occurs. The higher the need for variance in the innovation process, the higher the level of redundancy built into the relational structure through overlapping contexts of interaction. Redundancy seems again to emerge as a measure of inefficiency in the exchange structure when the flows are clearly determined in their content. On the contrary, however, redundancy offers a precious way to overcome potential difficulties in the interaction, whenever the characteristics of the task require more articulated and complex exchanges.

These observations are confirmed by the analysis of 3-clans, as reported in figures 5.6 and 5.7, despite the higher noise introduced in the estimate by the larger value used for the diameter. The higher the level of task complexity, the larger on average the size of the subgroups and the larger their number.

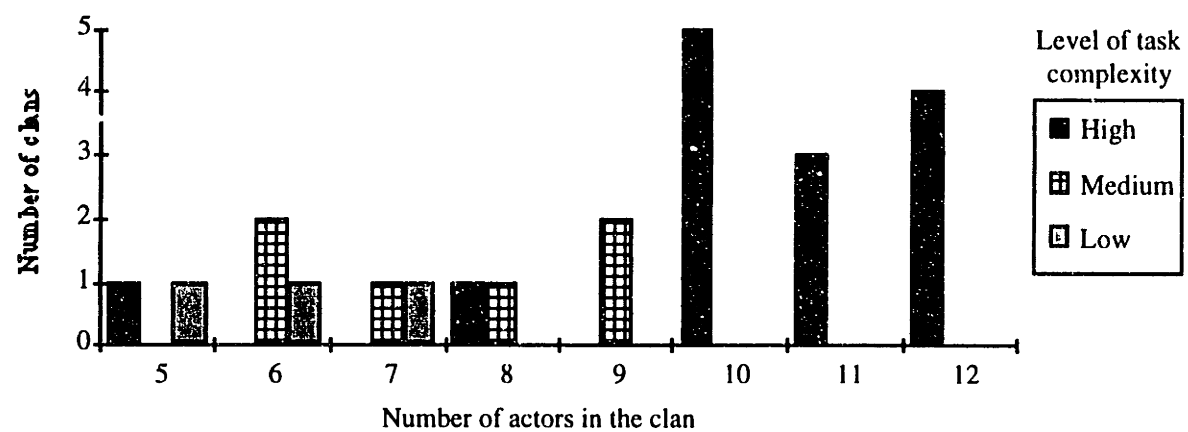


Figure 5.6 - Number and size of 3-clans by level of task complexity.

High task complexity:
R&D Projects

```
 Actor | 1 2 2   1 2         1 1   1 1   1 1     1 1 2 2 2
 Level | 1 1 3 4 9 2 1 8 2 6 2 3 7 4 7 3 0 5 9 5 6 8 0 4 5
-------+--------------------------------------------------
    13 | . . . . . . . . . . . . . . . . . . . XXX . . . .
    12 | . . . . . . . . . . . . . . . . . . XXXXX . . . .
    10 | . . . . . . . . . . . . . . . . XXXXXXXXX . . . .
     9 | . . . . . . . . . . . . . . . XXXXXXXXXXXXXXX . .
     8 | . . . . . . . . . . . . . XXXXXXXXXXXXXXXXXXX . .
     7 | . . . . . . . . . . . . XXXXXXXXXXXXXXXXXXXXX . .
     6 | . . . . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXX . .
     5 | . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXX . .
     3 | . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX .
     2 | . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     1 | . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Medium task complexity:
Technological Assistance
Projects

```
 Actor |     1 1 1 2 2       1 2   1 1 1   1 1 1   2 2   2
 Level | 4 7 1 4 8 0 3 1 2 8 3 1 5 5 7 9 3 0 2 6 6 2 4 9 5
-------+--------------------------------------------------
     4 | . . . . . . . . . . . . . . . . . . . . XXX . XXX
     3 | . . . . . . . . . . . . . . . . XXXXXXXXXXXXXXXXX
     2 | . . . . . . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXX
     1 | . . . . . . . XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Low task complexity:
Service Maintenance
Projects

```
 Actor |             1     1 1   1 1 1 1 1 1 1 2 2 2 2 2 2
 Level | 1 2 3 4 7 9 2 5 6 1 0 8 3 4 5 6 7 8 9 0 1 2 3 4 5
-------+--------------------------------------------------
     3 | . . . . . . . . . . . XXXXX . . . . . . . . . . .
     2 | . . . . . . . . . XXXXXXXXXXX . . . . . . . . . .
     1 | . . . . . . . . XXXXXXXXXXXXXXXXX . . . . . . . .
     0 | XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
```

Figure 5.7 - Functions clustered by joint membership in 2-clans at different levels of task complexity.

To control for possible sensitivity of the data to the use of observed rather than planned relational data, I compared group co-membership matrices for both 2-clans and 3-clans, using budget and billed data through the following steps: (1) I computed the group co-membership for 2-clans and 3-clans at different level of task complexity using billed data; (2) I repeated step 1 using budget data instead; (3) for each level of task complexity, I used the QAP correlation procedure to compare 2-clans co-membership matrixes resulting from billed and budget data; and (4) I repeated step 3 for 3-clans co-membership matrixes.

Table 5.6 reports the values obtained with the QAP correlation procedure, using 500 iterations. The procedure first correlates the two matrixes being compared, then permutes randomly rows and columns, and recalculates the correlation between the modified matrixes. This sequence is repeated for each iteration, thus generating a distribution of the correlation between the matrixes. A non-parametric estimate of the robustness of the results is obtained from this distribution and corresponds to the "proportion as large" value, which can be interpreted as a p-level. The values reported in table 5.6 show very large values of correlation between budget data and billed data at all levels of task complexity, both for 2-clans and 3-clans co-membership matrixes. These values are also robust according to the non-parametric estimates obtained.[7]

Table 5.7 - QAP correlation between budget and billed clan co-membership matrices.

		2-clans			3-clans		
	Budget	Level of task complexity			Level of task complexity		
Billed		High	Medium	Low	High	Medium	Low
	High	.51***	-	-	.43***	-	-
Level of task complexity	Medium	-	.46***	-	-	.45***	-
	Low	-	-	.40**	-	-	.41***

* proportion as large <.05
** proportion as large <.01
*** proportion as large <.001

[7] Technically, the procedure used as implemented by UCINET IV requires to specify a starting value to set off the random permutation and the numbers of iterations requested. The use of different starting values and different number of iterations did not generate significant changes with respect to the results reported.

5.6 Conclusions

After recognizing the importance of inter-organizational relationships in innovation development processes, we need to consider how such relationships should be structured. Using a relational perspective, this chapter contributed to this issue both theoretically and empirically. On a theoretical level, it elaborated a distinction among different levels of exchanges, introducing and formalizing the concepts of relational scale, scope and structural patterns, and linking them to the characteristics of the task jointly performed by the observed actors. Empirically, it presented a field test of six hypotheses derived from the theoretical definition of relational dimensions.

The intuitions behind the need for large investments in transactional activities to access external resources to solve complex problems found strong support in the data. The evidence contributes to grounding empirically one of the pillars of knowledge-based perspective of innovation processes. In addition to that, however, it also contributes to the theoretical debate showing the importance of consistency with respect to the unit of analysis used. Moreover, by widening the picture to include equivalent results with respect to characteristics of the relational sets activated and their interconnections, it showed how limited it is to focus only on some quantitative measures of exchange flows. On the contrary, the relationship between level of task complexity and relational scope and sub-groups structural patterns indicated the importance of the composition of relational sets.

It is fairly incomplete to limit any analysis to a measure of the amount of activities performed with other actors. Without a specific investment focused on capturing the overall network of relations, we would not be able to discriminate any further among different relational strategies. However, depending on the characteristics of the task at hand, choices could be made not only with respect to the volume of the exchange, but also whether to rely on direct or indirect contacts, to invest on few strong ties or to be embedded in larger (but weaker) relational sets, to invest in the coordination of a more dispersed relation structure and narrow down the internal competencies to a limited domain, or rather diversify internally and selectively activate few complementary linkages.

Other things being equal -i.e. the possibility of activating external ties, the presence of resources to invest internally etc.-, none of these decisions could be taken without carefully considering the type of joint work realized among the parties. Once more, the activation of external ties is not good or bad per se, but depends on the characteristics of the task at hand. More precisely, the ways on how to interact with other actors can be appropriately used to discriminate among possible alternatives using different leverages.

These results are important to further qualify the procedural coordination concept introduced in chapter 2 and used at a more micro level in chapter 4. While there is a diffuse consensus on the availability of different options to discriminate among alternative forms of contractual coordination mechanisms and govern the distribution of rights among the parties, this is less true with respect to the structuring alternatives available to govern the exchange of information. The concepts of relational size, scope and sub-group structural patterns offer a direct contribution to theoretically identify different action domains, which can practically guide the implementation of alternative structuring arrangements.

Implicit in the analysis performed in the chapter is the idea of fit between task characteristics and relational characteristics. This approach moves an information based perspective from the intra-organizational domain to the inter-organizational domain. However, it suffers from the same limitation characterizing these types of approaches.

While assumed, performance implications of fit between task characteristics and relational characteristics are not formally measured, nor tested. To complete the picture, I therefore need to show whether the correspondence between level of task complexity and relational size, scope and structural patterns are indeed indicative of higher level of performance or not. Chapter 6 is dedicated to this analysis.

CHAPTER 6
Network effects on actors' outcome

6.1 Introduction

Using network analysis to model inter-organizational procedural coordination mechanisms I showed the importance of considering both individual attributes and network constraints to understand the outcome of interaction processes. Once envisioned as embedded in a set of interconnected links varying in their strength and distribution, individual actions naturally become a function not only of exogenous attributes, but also of the network structure itself. In Chapter 5 I introduced the concepts of network size, scope and structure and presented empirical evidence linking them to the characteristics of the tasks performed by the actors involved, providing initial support for the importance of a complete analysis of actors' relational sets.

This representation of the effects of procedural coordination mechanisms on the observed outcome forces the researcher to specify a model where the dependent variable is related to a set of independent parameters and the influence of the network structure. What is the appropriate functional form to be used to make the estimate? What are the theoretical foundations of the different alternatives? What are the associated statistical issues and how can they be addressed?

In this chapter I complete the investigation of the role of procedural coordination mechanisms in affecting relationship outcome by answering these questions. Section 6.2 discusses the theoretical foundations for an application of structurally constrained actions in the context of innovation activities to show the incompleteness of attribute-based observation, whenever several actors are contributing to the final outcome. Section 6.3 introduces alternative econometric specifications to incorporate a network effect on individual outcome, discussing the related conceptual and methodological implications. Section 6.4 operationalizes the network effect model chosen, formulating the hypothesis and describing the relevant variables. Section 6.5 presents the analysis and discusses the results. Section 6.6 concludes relating the results obtained in this chapter with the rest of the thesis.

6.2 Network effects on innovative processes

Several studies on innovation examine the mechanisms by which individual choices are influenced in the process of generation and implementation of new ideas. Behavioral explanations identify specific constraints to innovative activities in the misalignment between the existing set of norms and routines and new ideas (Penrose, 1959; March, 1981; Nelson and Winter, 1982). Henderson and Clark (1990) analyze the history of the U.S. photolithographic equipment industry to show how incumbents failed to introduce and subsequently keep up with even apparently minor technological changes, but which were requiring major changes in engineering approaches and internal organization.

Mitchell's studies in the U.S. medical diagnostic imaging industry (1989; 1991; 1992) expand these observations to include not only the technological dimension of innovation, but also the commercial one. His data show that incumbents are less responsive to technological change, but outperform industry newcomers in redefining their commercial boundaries. Similar results are also obtained by economists, who use lock-in investments to model individual sub optimal choices and explain incumbents' resistance to changing their current assets base (Arrow, 1962; Reiganum, 1983).

Whatever the preferred perspective, it is still an open question whether the observed resistance to innovation is determined by some exogenous attributes of the subjects observed, or whether ti can be interpreted as the consequence of the embeddedness of these subjects in an interaction set (Granovetter 1985). Attribution based explanations focus on the actors observed (individuals, groups or organizations) and interpret their actions as a function of a set of objective characteristics. Size, age, organizational accountability and reliability are examples of such attributes, whose presence in the genetic code of an organization determines structural inertia and become the main explanatory factor for the frequently lost battle for change (Hannan and Freeman, 1984).

Although expressed in different terms, similar conclusions are reached by evolutionary models (Nelson abd Winter, 1977: Dosi, 1982). Individual actors are considered as operating in a larger set which partly constrains their actions, but this constraining effect is assumed by changes in some individual characteristics of the subject observed. While incorporating a dynamic perspective by monitoring the changes in the characteristics of the subjects observed, the latter remain the driving force in orienting actions and choices. Jovanovic (1982) model of industry evolution formally identifies in a demographic record at the individual firm level the key determinant of each status of the system. Similarly, although less formally, Suarez and Utterback (1995) analyze firms' characteristics and their survival in different industry under changing technological regimes and conclude by linking success stories in different stages of industry evolution to the combination of specific strategies and structures.

While more accurately incorporating the role of the external environment as partly endogenous to the system observed, even evolutionary models are ambiguous in the explanations of the role of such effect and how and by what forces it is produced. Or put differently, the actors observed are considered as if they were solely affected by the system, and not also affecting it with their actions and choices. The emergence of the so called Not Invented Here syndrome in R&D groups (Katz and Allen, 1982) is a good example of this process. The reluctance to consider ideas and solutions developed outside the internal group emerges the more the group is isolated from the external environment, and is reinforced over time by an increasing internal cohesion among its members.

Organization research has long recognized the existence of such processes and structural theories of action have modeled the subjects as constrained in their choices by the external environment through their relational set (Laumann et al., 1978). Studies on job attitudes (Ibarra and Andrews, 1993), individual perceptions (Krackhardt, 1990), group behavior (Gladstein, 1984) and more general on the definition of social contexts (Weick, 1979; Granovetter, 1985) show how attitudes, perceptions and actions derive from the context in which they are formulated. Subjects are influenced by their presence within a set of relations and at the same time contribute to influence the actions and the choices of all the other members in the set by their presence. The recursive nature of this influence process incorporates constraints to individual actions as an endogenous property of the system, determined by the whole set of actions and choices of all the actors involved.

6. Network effects on actors' outcome

Social network theories formalize the interaction between individuals and social structures by modeling actions and choices as a function of position or equivalence among the subjects (Marsden and Lin, 1982). In the first case, location in the relational set is observed as an objective property of each individual subject and related to the observed behavior (Wellman and Wortley, 1990; Fernandez and Gould, 1994). In the second case, individuals are clustered in groups homogenous by relational characteristics (ex. we are all suppliers of firms A, B and C), and their actions are observed to highlight commonalties deriving by indirect influence patterns within the network (Breiger, 1981; Burt, 1992).

The use of social network analysis provides the opportunity to analyze innovation processes as the result of individual actions embedded in a larger set. To evaluate the impact of the embeddedness of individual actors within an identified relational set, however, one should be able to model how such effect is reproduced, observe some change on individual outcome, and control for possible alternative rival hypothesis related to the underdetermined and overdetermined view of social action. As has been noted, in fact, it is one thing to say that networks have some kind of effect, and quite another to say how do they produce such effect and what precisely are these effects (Gartrell, 1987).

In the context of innovation activities this means essentially two things: first, to specify a model of network influence on individual action which incorporates the endogeneity of individual choices within the system; and second, to identify an appropriate outcome variable for the evaluation of the impact of the network structure. Instead of using data about network positioning as additional individual attributes, all the characteristics of network size, scope and structural patterns should therefore be included in relational terms. Both steps are necessary to assess if and how relational activities influence each individual actor's outcome. In the next sections I approach these issues first deriving the econometric specification of an endogenous model of network effect on individual outcome, and then using data on innovation projects to empirically test the impact on actors' performance of relational activities in new product development.

6.3 Models of network effect

In its simplest formulation, the estimate of a network effect on the observed outcome variable can be operationalized by the inclusion of an additional independent variable in multiple regression models. Haunschild (1993) presents data on interlocking directorates to test whether acquisitions propagate in the strategic arena through imitation processes as predicted by an institutionalist perspective. Among the independent variables, she uses the number of prior acquisitions completed by the firms with a common board member to operationalize the strategic action which should be imitated later on, including several controls and using Tobit regression models to account for truncated data. Her results show that those firms whose board members sit on boards of other firms which completed acquisitions in the past are more likely to pursue acquisition strategies.

Mitchell and Singh (1996) study how collaborative agreements influence entry and exits patterns in the U.S. hospital software system industry. They operationalize network activities using the number of agreements by category for each year of observation, thus focusing on network size. Distinguishing among development oriented, marketing oriented and generic collaborations they report different effects of relational activities. On the one hand, collaborations in development and marketing increase the likelihood of survival more than generic agreements when the environment changes gradually. On the other hand, in the emergence of environmental shocks (i.e. in their empirical settings a major regulatory change) firms with an already established network of relations are less likely to survive. Since not all the firms with prior collaborations exit the industry after the environmental shock, these results suggest the importance of differences in network scope -i.e. the composition of each individual network - to explain the observed effects. The non-relational nature of the data-coding procedure used, however, prevents the authors from incorporating any information on this key aspect.

Kogut and colleagues (1995) show how entry patterns in different sub fields of the semiconductor industry are influenced by the network structure of alliances and cooperative agreements promoted by incumbents to establish technological standards. They use betweennes centrality to model the role of incumbents in linking other organizations which would have little or no chance to interact otherwise, and network density to assess the collaborative opportunities in the industry. Betweenness centrality positively affected the probability of new entries in an emerging sub field, while network density did not.

Although easily applicable, these approaches assume the exogeneity of any network effect, with two important conceptual implications. First, the observed connections and their characteristics are modeled as an additional external constraint faced by the actors in their choices and become an objective attributional property of the interaction space. Second, the actors themselves can observe some manifestation of the network effect and in some cases rationally intervene to modify it (Burt, 1992).

Both aspects, however, have been debated methodologically and substantially. Methodologically, the undetected presence of endogeneity violates one fundamental assumption of estimation techniques and generates biased results. Substantially, organization research has long been assessing the interdependence between environmental pressure and individual action as an endogenous aspect of organization dynamics (Powell and Di Maggio, 1991). Similarly, the rationality of the observed behavior and the possibility of individual manipulation of the interaction variables has yet to find convincing support. In one of the few longitudinal studies of strategic action using a network analysis approach, Padget and Ansell (1993) document the rise and the fall of the Medici Family in the Renaissance Florence as the result of a strategic positioning in between multiple ties, but show no evidence for Cosimo de' Medici's rationality in pursuing this strategy.

The exogeneity assumption is therefore inappropriate to represent influence processes where any action itself is going to influence the future action structure (Marsden and Friedkin, 1994). To include these conceptual issues in the choice of the appropriate functional form and empirically test the impact of a network effect two steps must be taken: (a) we need to specify a network effect in a metric coherent with the assumptions and methods used by network analysis, and (b) we need to model the endogeneity. Several authors have recently worked on the first issue by including in the model a matrix of weights representing the links among the actors observed (Doreian, 1989). The network effect is represented with the complete set of direct and indirect ties summarized by an adjacency matrix, row normalized to consider the relative influence of each tie.

The endogeneity of the network effect can then be modeled in two ways. As a first approximation, we can think of interdependency as resulting from an unspecified source due to, for example, ecological processes or some generic unobserved environmental pressure (Marsden and Friedkin, 1994). While accepting the existence of some effect, we do not assume a direct influence of actors on one another, but rather that it propagates indirectly. Formally, this perspective can be represented with the so called network autocorrelation model:

$$y = \mathbf{X}\beta + \varepsilon \qquad \text{with} \qquad \varepsilon = \rho\mathbf{W}\varepsilon + \upsilon \qquad (1)$$

where y is a nx1 vector of the observed outcome, **X** is a nxk matrix of independent variables, **W** is a nxn matrix of influence coefficients,[1] ρ is the network autocorrelation parameter, and u is a vector of random perturbations. There is no direct effect of the network structure on the dependent variable. However, the error variance observed in the system is partly determined by the underlying network structure.

The main limit of this representation is the a priori exclusion of the role of direct ties. While important (Granovetter, 1973; Granovetter, 1985), however, indirect ties are only one way through which network effects influence the observed outcome. To include a direct effect, we need to rely on a simultaneous equation model, where the observed outcome is also one of the regressors, mediated by the network structure (Friedkin, 1990). Formally this can be represented with the so called network effect model:[2]

$$y = \alpha\mathbf{W}y + \mathbf{X}\beta + \varepsilon \qquad \text{with} \qquad \varepsilon \sim N(0, \sigma^2_\varepsilon I) \qquad (2)$$

where y is a nx1 vector of the observed outcome, **X** is a nxk matrix of independent variables, **W** is a nxn matrix of influence coefficients, α is the network effect, and ε is a random error term. The network relationships among the observed actors, operationalized through the **W** matrix, results in non-independent values of the dependent variable.

[1] The elements of W are usually taken to be positive, varying between 0 and 1, with each row sum equal to 1 to consider the relative influence (Doreian, 1981).

[2] The network effect model was originally presented by Doreian (1981) as the spatial effect model. In the terminological jungle of social sciences it can be also be indicated as a "lattice model" for spatial data, or the mixed regressive-autoregressive model, or the endogenous feedback model of social influence (Marsden and Friedkin, 1994).

Individual ties, both direct and indirect, contribute to influence directly your own outcome and that of others, and vice versa. The role and impact of the network effect is therefore separated from the unobserved variance and is directly estimated.

Both the autocorrelation model and the network-effect model are valid specifications to estimate the influence processes deriving from the embeddedness in a set of ties. As Marsden and Friedkin note (1994), the choice between the two depends on the conceptual representation of the mechanisms through which the subjects are affected in their actions by their relational sets. In the first case, the relational structure is somehow not discernible by the subjects involved. In the second case, on the contrary, the actors are themselves intentionally participating to the definition of their own relational structure with some kind of expectations. While certainly less undeterministic in the representation of the causes and effects of social forces, this position does not exclude in any way the cognitive limitations of the actors observed or their effective capability to drive the overall social structure in the desired direction. It simply assume that the subjects observed are consciously establishing a certain relational set for some kind of purpose. Yet, they might not be able to fully represent, understand or even acknowledge the extent of their own relational set, and, as a consequence, of the overall network structure as well.

Because of these a priori considerations, the econometric specification of the network effect model is more appropriate to study the influence of network processes in innovation activities and to test their impact on individual outcome. In the following section I describe the data I used for my analysis, how I operationalized the variables included in the model and the algorithms chosen for the estimation.

6.4. Empirical analysis

To perform the empirical analysis I continued to rely on the data collected in the basic and applied R&D organization in the steel industry (ALFA) I described extensively in Chapter 5 (Section 5.4). Within that setting, for the purpose of this analysis, I had to approach three different issues:

1) define a dependent variable to be used as a measure of units' performance;
2) identify a set of attributional variables to be included in the model as independent covariates;
3) generate the appropriate **W** matrix to represent network interdependencies.

To approach these issues coherently , I defined the single organizational unit as the unit of analysis. Data were therefore collected and elaborated at the Function level - i.e. an independent R&D unit, responsible for the completion of a certain number of projects within ALFA, and specialized in some specific area of research. Out of the 25 Functions of ALFA, one had to be excluded from the analysis due to the incompleteness of its data. That Function's demographics did not show any peculiarities which might determine biased estimates after this exclusion. The final sample is therefore represented by 173 innovation projects performed by 24 of the 25 Functions of ALFA during the 1994 fiscal year. In the following sections I describe in detail the operationalization of the dependent variable, of the independent covariates, and of the **W** matrix, and present the models used for the estimate.

6.4.1. Dependent variable

Measures of organization performance can be based on some objective parameter or on some subjective evaluation of a selected panel of judges (Van de Ven and Ferry, 1980). Research on new product development projects consider among the first type of indicators evaluations of adherence to budgets (cost or time based) and sometimes of some pre-specified quality levels (Clark, 1989; Nobeoka, 1993). Alternatively, the managers involved in the study might be asked to formulate a judgment in regards to their satisfaction with the projects and their development (Ancona and Caldwell, 1992).

In this study four factors guided the choice of the performance measures. First, as the unit of observation is the single Function, the performance measure has to be at the Function level. Second, since the time of observation of ALFA and its projects was confined to 1 year, any performance measure used must refer to the time span observed. Third, the parameter needs to be visible and considered by the Functions, if we want to admit its usefulness for an internal check of past activities which can be used to reorient future actions. Fourth, the impossibility of forming a reliable panel of judges suggested that some kind of objective parameter be identified.[3]

To accommodate all these different issues, I decided to use a budget-based measure of performance, computed as the difference between the amount of man hours used by a function to perform the projects for which it was responsible and the amount of man hours originally budgeted. The performance indicator is computed separately for each level of task complexity. Each Function is therefore characterized by three different performance indicators, one recording its ability to adhere to the budget for projects of high task

[3] Internally, aside from a self evaluation by the Function Manager and an evaluation by its direct supervisor (Department director), it was not possible to collect other informed opinions on the activities performed by each single Function. As a consequence, it was not possible to identify a panel to verify some basic conditions for the use of subjective evaluations such as for example inter-rater reliability coefficients. Moreover, for confidentiality reasons, it was not possible to involve external subjects (ex. partners in multi-firm projects, EU inspectors for EU financed projects) who might have been able to judge Functions performance because of their direct involvement in a project.

complexity, one for projects of medium task complexity, and one for projects of low task complexity.[4]

The use of man hours instead of monetary figures is useful to avoid a common bias of budget based measures where it is always difficult, if not impossible, to distinguish the capital and labor components of the values observed. Moreover, while not controlling for possible differences in the labor component of project costs (ex. one hour of a senior researcher costs more than one hour of a laboratory technician), it still offers an easily interpretable measure of efficiency.

Given the way they are constructed, performance measures need some care in interpretation. As they are the difference between the observed amount of resources used and the planned amount of resources for a given set of projects, positive values indicate higher use of resources than planned, and negative values indicate lower use of resources than planned. Positive values therefore indicate lower levels of efficiency, and negative values higher levels of efficiency. Since the order of variance is reversed with respect to usual representation of performance measures, the interpretation of the results has to be made accordingly. For a given variable, a negative coefficient estimate will mean a positive impact on performance, while a positive coefficient estimate will mean a negative impact on performance.

6.4.2 Independent covariates

Several studies show that organizational performance depends on the characteristics of the task performed and on the characteristics of the organization observed (Gooding and

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[4] For a complete description of the analytical steps taken and how I operationalized task complexity see Chapter 5, p. 177-179.

Wagner, 1985). To control for these effects, I include in the estimate four covariates. This set of covariates is not complete and the sample size does not allow me to further enlarge it. However, it considers the most relevant factors affecting organizational performance as indicated by previous research (Gooding and Wagner, 1985).

The first control variable is the size of the organizational unit, operationalized by counting the number of employees for each Function. No data are available to evaluate the investment in physical assets at the function level. While this shortcoming could result in biased estimates if manufacturing activities are involved, studies on the productivity of R&D show that possible scale effects are related primarily to investments in a critical mass of people (Griliches, 1984).

A simple count of the number of people limits any analysis to the observation of the quantity of resources employed, underestimating the importance of information on their quality. To control for the characteristics of the resources used by the Functions I use two different variables. The first one considers the level of education of each employee working within a Function. I use a 3-point Likert scale to distinguish among people without a formal education (1), people with a high school degree (2) and people with an undergraduate degree (3). The educational system of the country where ALFA operates is different from the North American one in several aspects: (a) Technical high schools are designed to produce at the end of the 5 year period technicians to be directly employed in their area of specialization; while apparently limited, the education level reached is sufficient for the individual to begin working on specific issues and gain considerable experience and expertise over the years through some sort of informal training on the job; (b) undergraduate program are usually longer in duration and more specialized in their curricula than US programs; given the content of the courses and the length of the program, they can be considered as a combination of an undergraduate degree and a master degree; (c) within the educational system, doctoral degrees were only recently introduced and even in technical fields tend to produce resources for the academic environment, rather than for the industry. While nominally different, the range of variation of the education variable is therefore comparable to that of other studies performed on North American samples.

The quality of the resources employed is not only an objective factor of the observed unit, but is also influenced by the use of that resource within a specific setting. In organization research, individual tenure within the organization has been shown to affect performance (Ancona and Caldwell, 1992; Virany et al., 1992). Longer tenure within the organization facilitates the embeddedness in the internal dynamics and the approach to routine activities, but can turn into a limit whenever facing new conditions by constraining change (March, 1981). Whenever an organizational unit is observed, to evaluate the quality of its resources it is therefore important to consider the distribution of the tenure within the organization of its members. Following Ancona and Caldwell (1992), I use as the second variable to control for the quality of the resources employed the coefficient of variation of tenure, which is a measure of the dispersion of the tenure of the members of the Function observed.[5]

The fourth covariate included in the estimate is used to control for possible differences in the project portfolio managed by each Function. The performance measure,

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[5] For each Function, the coefficient of variation tenure is the ratio between the standard deviation and the mean of the tenure of its employees. Since the hiring date was considered strictly confidential, I operationalized organizational tenure as follows. The individual record of ALFA employees is progressively increasing and reflects the hiring order. While not informative to precisely indicate the hiring time, the individual record rank order each employee on the basis of his/her tenure within the organization relative to all the others. For each employee, the organizational tenure indicator was therefore operationalized as the ratio between (a) the difference of the largest individual record (i.e. corresponding to the last employee hired by ALFA) and the employee's one, and (b) the largest individual record. The indicator varies between 0 (shortest tenure within the organization) and 1 (longest tenure within the organization).

in fact, is evaluated over the full set of projects under the Function responsibility, and does not discriminate among different profiles of project portfolios. I therefore partitioned all the projects performed by ALFA by Function and calculated the average project size administered as the mean of the projects budget. I use this as a measure of inter-function differences in the projects administered.

Finally, to control for the robustness of the representation of a network effect through the **W** matrix as described below, I included a fifth covariate which is an attributional indicator of network activities. The variable is the percentage of work performed internally over the total amount of work performed by the Function measured in man hours. Technically, the variable is the diagonal of the asymmetrical, valued matrix $\mathbf{V}^{t,s}$ described in Chapter 5 (see p. 175), and is a typical attributional indicator used to operationalize external dependency (Pfeffer and Salancik, 1978; Van de Ven and Walker, 1984; Walker and Weber, 1984). If a relational representation of network effect is more appropriate than an attributional one, the inclusion of the variable in the model should decrease model efficiency and should not affect the estimates obtained without it.

6.4.3 The W matrices

In general terms, the **W** matrix is used to operationalize in the model the network structure. As for any matrix-based measure of relationships, each cell reports information on the tie between two observed units. It can be computed on the basis of either relational or positional criteria (Doreian, 1989; Marsden and Friedkin, 1994). For the purpose of this analysis, I adopted a relational approach to derive the **W** matrix.

The number of hours bought (or sold) by a Function from (or to) another were cumulated for all the projects performed during 1994 in an asymmetrical, valued adjacency matrix at the Function level. The resulting relational data use the number of hours bought (or sold) by a unit from (or to) another to measure the existence of a tie and express its strength, distinguishing between ties received and sent. In chapter 5 no major differences emerged between budget and billed data with respect to a representation of network scope and structure. Budget data, however, were found to underestimate the volume of transactions occurred in the system (network size). Billed data were therefore used here to compute the initial adjacency matrix (**A**).

The **A** matrix was subsequently partitioned by level of task complexity in three different matrices ($\mathbf{V}^t$). Diagonal elements of each adjacency matrix ($\mathbf{V}^t$) were set to zero (Doreian, 1981) and the resulting matrices ($\mathbf{D}^t$) were then row normalized to obtain three **W** matrices ($\mathbf{W}^t$), one for each level of task complexity. A non-zero entry in each $\mathbf{W}^t$ matrix represents the amount of man hours bought by a row Function from a column Function over the total amount of man hours bought by the row function.

This operationalization of the **W** matrix offers a representation of what we can call *client* networking activities. It considers the directionality and the relative importance of all the ties sent by a Function to perform its own projects. As discussed in Chapter 5, however, different units interact not only directly, but also by being involved in projects out of their responsibility where some of their specific competencies are required. These interactions represent additional opportunities to benefit from (or to be limited by) networking activities. We can call these type of interactions *server* networking activities. To consider also the effect of *server* networking activities, I constructed another set of three **W** matrices ($\mathbf{W}^t_{-1}$), first transposing the $\mathbf{D}^t$ matrices, and then row normalizing them. A non-zero entry in each resulting $\mathbf{W}^t_{-1}$ matrix is therefore the amount of men hours sold by a row Function to a column Function over the total amount of men hours sold by the row function.

6.4.4 The network effect model

Following Doreian (1982), I use maximum likelihood iterative techniques as implemented by Friedkin (1992) to calculate an estimate of the parameters of the recursive model of equation (2). The outcome of this routine which runs under GAUSS is interpretable as in any regression model. The β coefficients associated to the set of independent covariates indicate the directionality and the magnitude of the influence of each variable on the performance of the Functions. The α coefficient can be interpreted as the influence of networking activities on the performance of the Functions. In this case, negative values indicate a positive effect of networking activities on Functions' performance, while positive values indicate a negative effect. For each model a measure of fit is obtained by the squared correlation of the observed and predicted values (Doreian, 1981). While roughly similar to the R-squared in standard OLS models, this is a non-parametric measure of fit and should therefore be interpreted cautiously.

A series of network effect models is estimated to answer different questions. First, I am interested in assessing how and to what extent individual unit outcomes are influenced by their networking activities. Second, I want to see whether this influence differs in its magnitude and direction by the type of tasks performed. Third, I want to compare a simultaneous estimate of a relational and an attributional operationalization of networking activities. To investigate these issues I estimate the models reported in table 6.1 and compare their results.

To assess the role of networking activities on individual outcome I estimate two sets of network effect models using the different specifications of the **W** matrix. In the first set of models, I use the $\mathbf{W}^t$ matrices which are the row normalized matrices of the number of hours sold by the column unit to the row unit to complete the row unit projects. The $\mathbf{W}^t$ matrices measure the *client* effect of using external resources to achieve a given outcome.

In the second set of models, I use the $\mathbf{W}^t_{-1}$ matrices which are the row normalized matrices of the number of hours sold by the row unit to the column unit to complete the column unit projects. The $\mathbf{W}^t_{-1}$ matrices measure the *server* effect of being involved in networking activities on achieving a given outcome. The distinction between the two sets of models is extremely important. In the first case, I am estimating the impact on unit A's performance of its reliance on other units to complete its projects. In the second case, I am estimating the extent to which the involvement of unit A in other projects affects its performance. In both cases, if the outcome of a Function depends on its networking activity, I expect the α coefficient to be statistically significant.

Network effects might vary depending on the content of the activated ties, though. As I showed in chapter 5, the size, scope and structure of the observed relationships differed significantly depending on the type of task performed. To test for a difference in magnitude and direction of the network effect on individual units' performance I estimate both models as previously defined for different levels of task complexity (High, Medium and Low). This set of estimates, combined with the first set of estimates, provides a two-way comparison of the *client* and *server* network effect for different levels of task complexity.

Table 6.1 - The models estimated.

Level of task complexity	Network activity: Direct	Network activity: Indirect
High	*Model 1*: $y = \alpha W^{H} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} \begin{bmatrix} \text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \end{bmatrix} + \varepsilon$	*Model 7*: $y = \alpha W^{L}_{-1} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} \begin{bmatrix} \text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \end{bmatrix} + \varepsilon$
	Model 2: $y = \alpha W^{H} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} \begin{bmatrix} \text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \\ \text{\%\_Internal\_work} \end{bmatrix} + \varepsilon$	*Model 8*: $y = \alpha W^{H}_{-1} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} \begin{bmatrix} \text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \\ \text{\%\_Internal\_work} \end{bmatrix} + \varepsilon$

Table 6.1 - continues.

Level of task complexity	Network activity: Direct	Network activity: Indirect
Medium	*Model 3*: $y = \alpha W^{M} y + \begin{bmatrix}\beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4\end{bmatrix} \begin{bmatrix}\text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size}\end{bmatrix} + \varepsilon$	*Model 9*: $y = \alpha W^{M}_{-1} y + \begin{bmatrix}\beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4\end{bmatrix} \begin{bmatrix}\text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size}\end{bmatrix} + \varepsilon$
	Model 4: $y = \alpha W^{M} y + \begin{bmatrix}\beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5\end{bmatrix} \begin{bmatrix}\text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \\ \text{\%\_Internal\_work}\end{bmatrix} + \varepsilon$	*Model 10*: $y = \alpha W^{M}_{-1} y + \begin{bmatrix}\beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5\end{bmatrix} \begin{bmatrix}\text{Function\_size} \\ \text{Education\_level} \\ \text{CV\_tenure} \\ \text{Av\_project\_size} \\ \text{\%\_Internal\_work}\end{bmatrix} + \varepsilon$

Table 6.1 - continues.

	Network activity	
Level of task complexity	Direct	Indirect
Low	*Model 5*: $y = \alpha W^{L} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} \begin{bmatrix} Function\_size \\ Education\_level \\ CV\_tenure \\ Av\_project\_size \end{bmatrix} + \varepsilon$	*Model 11*: $y = \alpha W^{L}_{-1} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} \begin{bmatrix} Function\_size \\ Education\_level \\ CV\_tenure \\ Av\_project\_size \end{bmatrix} + \varepsilon$
	Model 6: $y = \alpha W^{L} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} \begin{bmatrix} Function\_size \\ Education\_level \\ CV\_tenure \\ Av\_project\_size \\ \%\_Internal\_work \end{bmatrix} + \varepsilon$	*Model 12*: $y = \alpha W^{L}_{-1} y + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} \begin{bmatrix} Function\_size \\ Education\_level \\ CV\_tenure \\ Av\_project\_size \\ \%\_Internal\_work \end{bmatrix} + \varepsilon$

The analysis presented in chapter 4 showed that different combinations of task characteristics and relational activities were associated with different outcomes. More complex tasks characterized by higher levels of interaction among the parties through more elaborated procedural coordination mechanisms generated higher costs, but provided higher opportunities for learning. Since the measure of performance used in this analysis is essentially an efficiency measure, I expect to observe the value of the α coefficient to increase algebraically with decreasing levels of task complexity (i.e. *ceteris paribus*, strategies based on higher reliance on outside sources for less complex tasks are comparatively less efficient).

Table 6.2 - Hypothesized relationships and expected results.

	Hypothesis	Expected result
1a	*Client* networking activities influence unit's performance	$\hat{\alpha}_{[1,6]}$ statistically significant
1b	*Server* networking activities influence unit's performance	$\hat{\alpha}_{[7,12]}$ statistically significant
2a	The influence of *Client* networking activities varies by level of task complexity	$\hat{\alpha}_1 < \hat{\alpha}_3 < \hat{\alpha}_5$
2b	The influence of *Server* networking activities varies by level of task complexity	$\hat{\alpha}_7 < \hat{\alpha}_9 < \hat{\alpha}_{11}$
3	Relational estimates of network effects are better than attributional ones	$FIT_1 \geq FIT_2$; $FIT_3 \geq FIT_4$ $FIT_5 \geq FIT_6$; $FIT_7 \geq FIT_8$ $FIT_9 \geq FIT_{10}$; $FIT_{11} \geq FIT_{12}$

As the final step in the analysis, I include in each estimate the set of independent covariates described before, with and without the indicator of amount of work performed internally by the observed unit. I use this indicator as an attributional measure of networking activities, included in the model to test for the robustness of the relational measure used in the network-effect specification chosen. Since no formal comparison to evaluate the impact on the overall model of the inclusion of an additional regressor is available in this case, I expect the estimates (both the coefficients and the model-Fit) to be stable after the inclusion of the additional variable. Table 6.2 summarizes the expected results.

6.5 Results[6]

6.5.1 Descriptive statistics

An examination of the demographic characteristics of the units observed shows the presence of variance in the set. The size of the unit varies between a low 3 employees for Function 7 to a high 36 for Function 6, with an average of 12 (figure 6.1). Each Function is responsible for an average of 6 projects (figure 6.2). Function 1 manages the largest number of projects (15), while Function 22 is the only one not directly responsible for any project. The average size of the projects administered is around US$ 340,000, with three Functions (12, 21, and 24) administering projects with an average budget higher than 1 million US$ (figure 6.3). Larger units manage more projects, as the size of the Function is highly and positively correlated with the number of projects administered ($r = .73$).

[6] For confidentiality reasons, all the Functions information is coded so that none could be recognized in the analysis.

However, larger units do not manage bigger projects (correlation between unit size and the average size of the projects administered = .07).

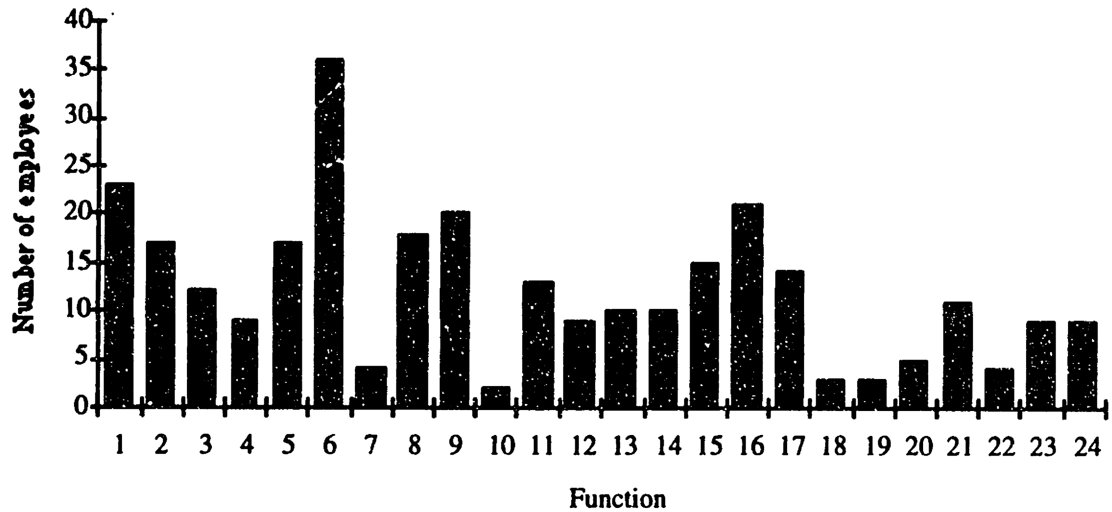

Figure 6.1 - Functions by size.

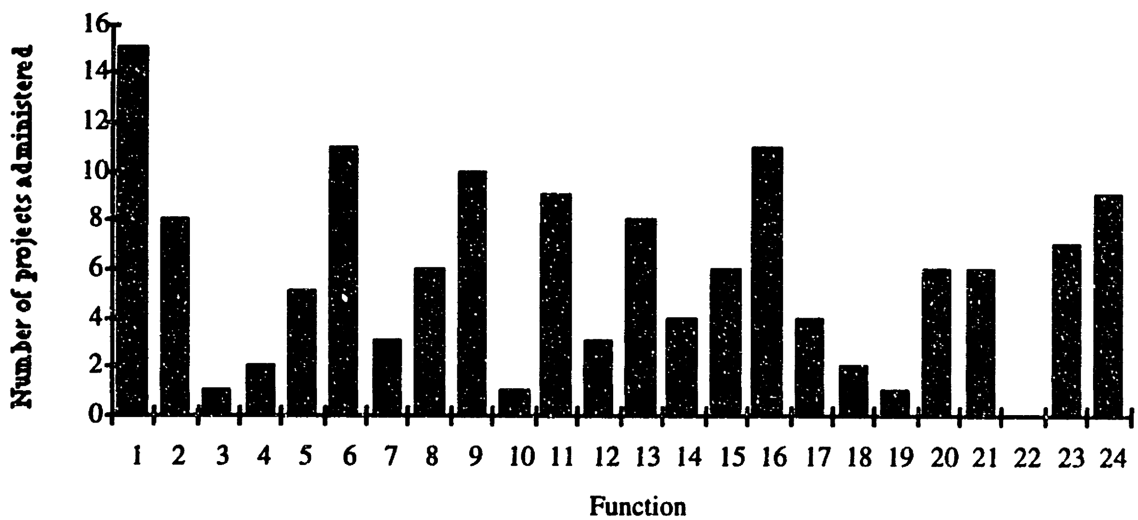

Figure 6.2 - Number of projects by function.

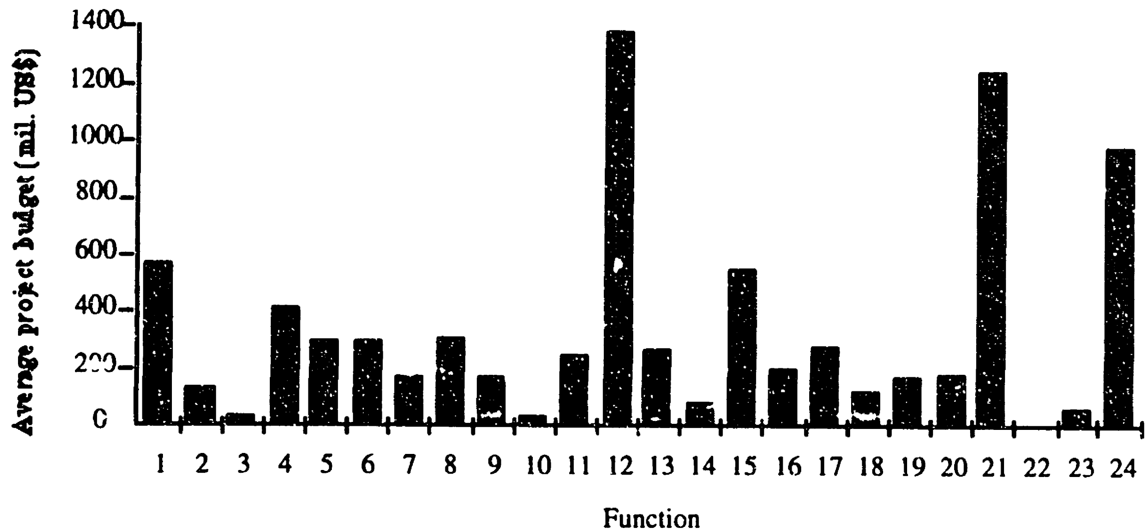

Figure 6.3 - Average size of projects administered by the Functions.

Within ALFA, excluding staff members who were not included in this analysis, 83 employees have no degree, 73 have an high school degree, and 137 have a University degree. Different levels of education are generally represented in each Function (figure 6.4). This is not unexpected and reflects the kind of work performed within ALFA, where each specialized Function needs some qualified researchers as well as some laboratory technicians who can support the theoretical work and operate the machinery for the experiments.

Members' tenure with ALFA also varies by Function (figure 6.5). The coefficient of variation tenure is greater than 1 in four cases (Functions 1, 7, 12, and 18), showing cases where the employee base includes members with both high and low organization tenure. All the other values are evenly distributed between 0 and 1, showing variance among the other units, although lower in absolute terms with respect to the first four.

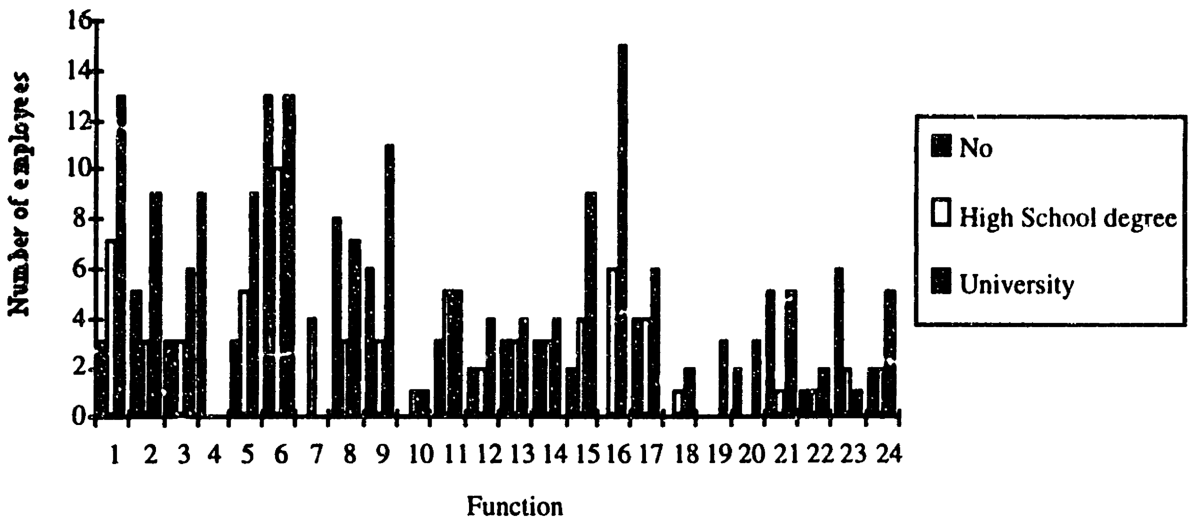

Figure 6.4 - Education level by Function.

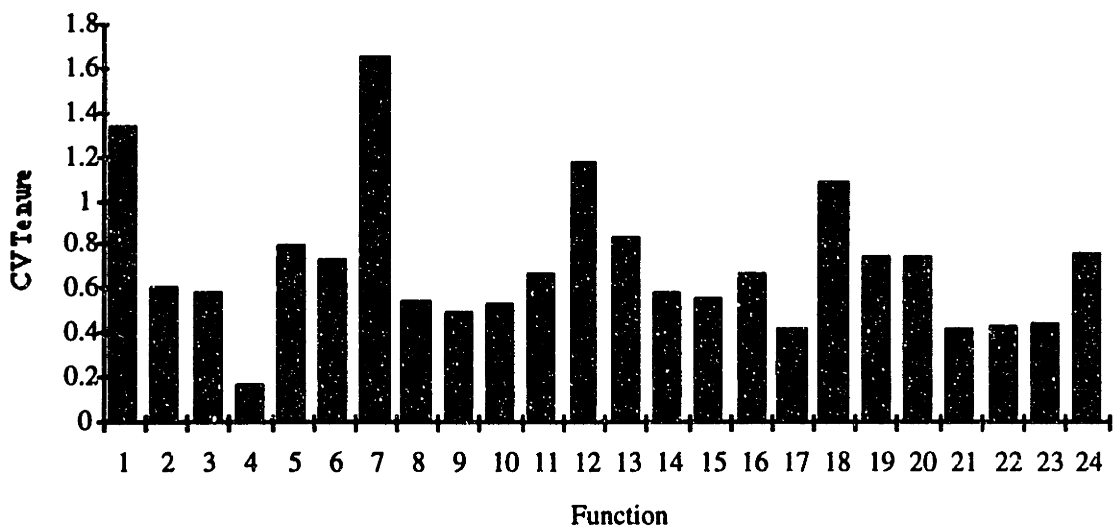

Figure 6.5 - CV Tenure by Function.

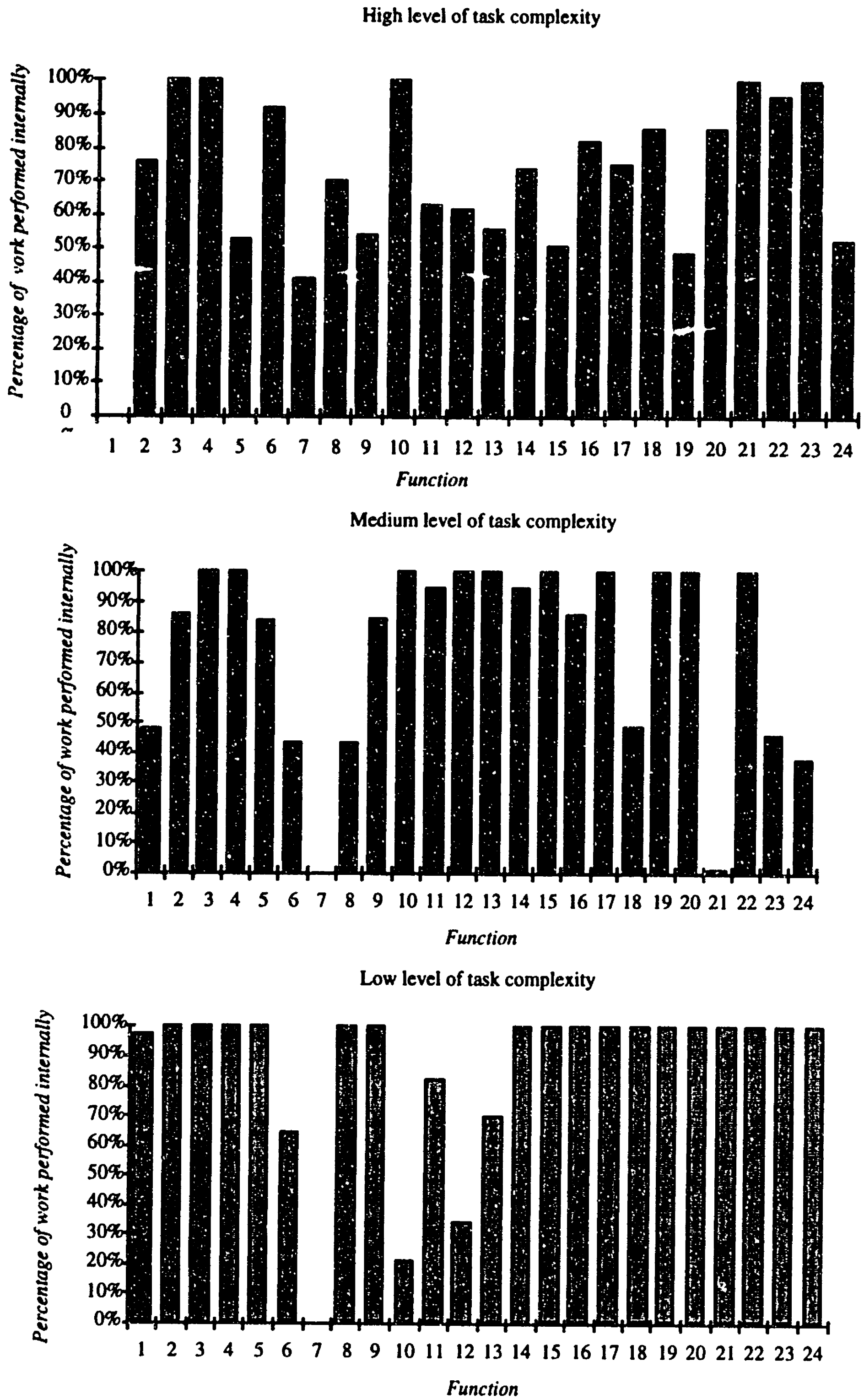

Figure 6.6 - Percentage of internal work performed by each Function by level of task complexity.

The involvement of other units varies not only by Function, but also by level of task complexity (figure 6.6). For projects characterized by a high level of task complexity (R&D Projects), on average there is a higher involvement of other units. About 30% of the men hours budgeted is bought from outside the Function responsible for that project. This percentage decrease to about 25% for projects characterized by a medium level of task complexity (Technological Assistance Projects), and drops to about 14% for projects characterized by a low level of task complexity (Service Maintenance Projects).[7] Moreover, while only 5 Functions performed all their R&D Projects with internal resources, 10 Functions performed all their Technological Assistance Projects internally, and 17 Functions performed all their Service Maintenance Projects internally. These observations confirm that the indicator records in a different way one of the results obtained in Chapter 5, where the size of network activities, i.e. the amount of relational exchanges, varied by the type of task performed.

6.5.2 Regression results

The network effect model chosen for the estimate relies on the usual assumptions of regression models. Table 6.3 reports the correlation matrix of the regressors included in the various models. The network effect variables are the matrix product of the different **W** matrices and the corresponding vector of performance measures. A general inspection of the values reported does not point to the presence of multicollinearity among the regressors. Large values refer only to the correlation between the coefficient of variation tenure and the percentage of work performed internally, measured by different levels of task complexity.

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[7] For a description of the different types of projects and how I operationalized complexity see Chapter 5 p. 177-179.

Since only two of the four variables are simultaneously present within the same model, in the absence of other significant pairwise correlation the efficiency of the estimates should not sensibly be affected.

Table 6.3 - Correlation matrix and univariate statistics.

		1	2	3	4	5	6	7
	Covariates							
1	Unit size	-						
2	Education	-0.06	-					
3	CV Tenure	-0.05	0.34	-				
4	Av. Project Size	0.07	-0.05	0.16	-			
5	% of internal work (task comp. = high)	-0.19	-0.36*	-0.64***	-0.21	-		
6	% of internal work (task comp. = med.)	-0.14	0.17	-0.39*	-0.30	0.12	-	
7	% of internal work (task comp. = low)	0.20	0.01	-0.55***	-0.09	0.10	0.19	-
	Network Effect: Direct							
8	$W^H y^H$	0.06	0.03	-0.39*	0.18	-0.04	0.19	0.21
9	$W^M y^M$	0.31	-0.10	-0.10	0.26	0.03	-0.51**	0.17
10	$W^L y^L$	-0.13	-0.08	0.21	-0.01	-0.17	0.13	-0.31
	Network Effect: Indirect							
11	$W^H_{-1} y^H$	-0.22	-0.11	-0.29	-0.10	0.10	-0.03	0.06
12	$W^M_{-1} y^M$	0.28	0.27	-0.17	-0.18	-0.01	0.20	0.30
13	$W^L_{-1} y^L$	0.21	0.36*	0.25	-0.01	-0.29	-0.07	-0.10
14	Mean	12.50	2.00	0.71	341.12	0.72	0.75	0.86
15	Standard deviation	7.87	0.40	.33	368.75	0.25	0.32	0.28
16	n	24	24	24	24	24	24	24

* $p<.1$, ** $p<.05$, *** $p<.01$

Table 6.4 - Effects on performance of *Client* networking activities (Standard errors in parenthesis).

Variable	*Model 1*	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
constant	-176.01	-1679.81	-451.69	-274.37	-452.21*	170.93
	(1100.30)	(1766.85)	(544.04)	(553.93)	(321.32)	(277.37)
α	-.19	-.07	.12	-.04	.99**	.99**
	(.28)	(.29)	(.28)	(.29)	(.44)	(.44)
size	-30.93*	-23.48	26.06**	26.11**	3.95	9.15*
	(23.29)	(23.83)	(11.66)	(11.63)	(6.79)	(5.25)
education	164.12	260.91	-37.83	26.11	177.41	310.37***
	(492.25)	(495.85)	(243.36)	(257.07)	(143.70)	(110.37)
CV Tenure	-682.34	-111.11	451.64*	318.15	25.38	-401.60***
	(610.83)	(743.53)	(300.44)	(337.63)	(177.21)	(152.01)
Av. project size	1.06***	1.08***	.06	.05	-.02	-.01
	(.33)	(.32)	(.16)	(.16)	(.10)	(.07)
% internal work		1120.90		-253.86		-786.02***
		(1013.63)		(345.28)		(178.82)
FIT	.32	.03	.26	.27	.21	.03

* p<.1, ** p<.05, *** p<.01

With the exception of the correlation between the percentage of work performed internally measured for a medium level of task complexity and the *client* network effect for the same type of tasks, there is no significant correlation between the relational representation of networking activities and the attributional one. This first examination starts to highlight the differences between the two measures. While the attributional one, in this case, includes information only on the size aspect of relational activities, the second one incorporates information on the size, the scope and the structural patterns of such activities. Instead of being considered alternative indicators of the same construct, the correlation analysis suggests to interpret them as two separate variables capturing different concepts.

The first set of estimates, reported in table 6.4, focuses on the effect of *client* networking activities on Function performance, with and without the indicator of the percentage of internal work included in the regression. The second set of estimates, reported in table 6.5, focuses on the effect of *server* networking activities. The estimate of a direct network effect on performance is statistically significant only for low levels of task complexity ($\hat{\alpha}_5 = .99$, $p<.05$). Although the α coefficients are individually not statistically significant for high ($\hat{\alpha}_1 = -.19$, n.s.) and medium ($\hat{\alpha}_3 = .12$, n.s.) levels of task complexity, their between-task comparison shows the expected trend. A positive effect of *client* networking activities on performance for projects with high task complexity becomes negative for projects with medium task complexity and increases its negative effect for projects with low task complexity. While involving external resources for more complex projects seems to improve the ability of the Functions to adhere to their own budget, this turns to be a disadvantage for less complex projects.

Similar results are obtained examining the estimates of a *server* network effect. The α coefficients are individually statistically significant both for high ($\hat{\alpha}_7 = -.29$, $p<.10$) and for low ($\hat{\alpha}_{11} = .44$, $p<.10$) levels of task complexity, while not for medium levels ($\hat{\alpha}_9 = -.12$, n.s.). Their comparison, however, confirms the same trend observed in the direct network effect models. *Server* relational activities have a positive effect on individual unit performance for projects characterized by high levels of task complexity. This positive effect on performance decreases for projects characterized by medium levels of task complexity and becomes negative for those low on task complexity. The benefit from networking activities depends on the content of the task performed.

These results are obtained in all the models after controlling for the effect on performance of the other covariates. The size coefficient is significant in almost all the models estimated, although varies in its sign depending on the level of task complexity, showing a positive effect for R&D projects, and a negative effect for Technological Assistance and Service Maintenance projects. The average project size coefficient is shown to negatively affect performance for R&D projects, but has no effect on other kinds of projects. The estimates for the education variable and the coefficient of variation tenure are highly unstable in all the models and do not seem to significantly account for performance differences among the Functions.

Table 6.5 - Effects on performance of *Server* networking activities (Standard errors in parenthesis).

Variable	*Model 7*	*Model 8*	*Model 9*	*Model 10*	*Model 11*	*Model 12*
constant	60.05	1301.08	-493.45	-348.35	-88.05	510.80**
	(1069.72)	(1723.11)	(540.97)	(576.95)	(319.41)	(272.50)
α	-.29*	-.25	-.12	-.11	.44*	.39***
	(.22)	(.22)	(.19)	(.20)	(.34)	(.19)
size	-37.91**	-30.32*	29.42***	28.12***	-.94	4.86**
	(22.61)	(23.22)	(11.73)	(11.88)	(6.75)	(5.16)
education	96.34	209.42	17.59	73.29	46.68	195.70**
	(478.68)	(483.27)	(244.63)	(255.32)	(142.85)	(110.19)
CV Tenure	-731.98	-267.35	391.66*	288.71	21.96	-406.92***
	(595.99)	(722.30)	(301.32)	(334.06)	(176.16)	(157.80)
Av. project size	.99***	1.05***	.06	.03	-.01	-.01
	(.32)	(.32)	(.16)	(.16)	(.09)	(.07)
% internal work		976.61		-224.93		-804.53***
		(989.89)		(338.31)		(171.13)
FIT	.36	.02	.27	.28	.20	.01

* p<.1, ** p<.05, *** p<.01

The overall fit of all models without the measure of the percentage of work performed internally varies between .36 and .20. These values can be considered satisfactory given the number of observations and the dependent variable chosen, adding support to the robustness of the estimates obtained. The models' fit, however, drops substantially after the inclusion of the measure of the percentage of work performed internally, as can be see comparing Models 1, 5, 7 and 11 with Models 2, 6, 8, and 12 respectively. Even in the cases of Models 3 and 4, and 9 and 10, the inclusion of the additional regressor neither improves the model fit, nor changes the directionality of the estimates. In general, therefore, the attributional representation of the volume of network activities seems to be inefficient to evaluate its impact on performance, when a more complete operationalization of relational activities recording also information on the scope and on the structural patterns of the network is included in the model.

6.6 Discussion and conclusions

The analysis presented in this chapter added two key elements to the conceptual framework introduced in chapter 2 and developed through different stages and empirical tests in the rest of the dissertation. It (a) demonstrated the existence of a relationship between networking activities and units' performance, and (b) made this effect contingent upon the nature of the task jointly performed.

The econometric derivation of models including a network representation of relational activities showed the importance and the implications of an examination of such activities going beyond attributional indicators. By using a matrix representation of inter-actor ties we are able to include in a model information on several characteristics of relational activities. The amount of exchanges among the observed units (network size), the variance in their relational set (network scope) and the structural patterns of the whole set of ties are considered simultaneously to become a direct determinant of individual outcome. The embeddedness in a relational set which influences the actions of its members is operationalized by combining the algebraic representation of inter-actor relations and inferential statistics, showing that alternative metrics can be used to estimate the influence of networking activities with traditional statistical tools.

This conceptual and practical step is strictly linked with the analysis performed in Chapter 5, which showed the relevance of distinguishing different dimensions of network characteristics. On the one hand, after understanding the meaning and the practical implications of network size, scope and structural patterns we are able to hypothesize their combined effect on the outcome of each one of the actors observed. On the other hand, once we have assessed this influence, the subsequent step would be the analysis of the extent to which each single component of the network effect contributes to influencing the outcome. This is a very practical question with direct managerial implications. Should we invest to increase the volume of the exchanges among the actors? Or should we invest to diversify their relational set, encouraging the contacts among multiple units or in different contexts? Or should we present to each unit its networking strategy as a fundamental determinant of its performance to be pursued along all the different dimensions of relational activities?

The combination of the results obtained in this chapter with those obtained in chapter 5 suggests the importance of a wider perspective on relational activities as a critical area for strategic decision making. The regression analysis performed in this chapter shows that indeed there might be benefits from the combination of internal and external resources. The results presented in chapter 5 show how we can articulate relational activities to achieve these results. Using the same theoretical terms introduced in chapter 2, this last analysis proves the impact on performance of procedural coordination mechanisms, and the analysis presented in chapter 5 articulates such mechanisms in relational terms. This articulation emerges therefore as a key strategic issue, and its implementation can be usefully guided by adopting a relational perspective. The problem ceases to be limited to the aspects highlighted in chapter 4, where the attention was focused on traditional organization design variables like communication channels, frequency of communication and the like. Rather, the introduction of a social network perspective shows the theoretical relevance of associating to the structuring choices of inter-organizational activities a corresponding relational representation and how this can be implemented.

These are strong results which link statistically and not solely descriptively actors' performance to the characteristics of relational activities. The sensitivity of the analysis to the inclusion of a task effect takes these observations one step further. What emerges from the regression analysis is that the impact of networking activities on the performance of the units observed varies with the characteristics of the task performed through the activated ties. Higher levels of task complexity are associated with a positive impact on individual units performance, while lower levels of task complexity are associated with a negative one. The implications of investing in relational activities is therefore contingent upon the characteristics of the tasks performed within the relations. The decision of activating external ties is not going to affect positively or negatively the outcome of the actors involved per se. On the contrary, it strongly depends on the characteristics of the activities jointly performed and on the congruence of the procedural mechanisms chosen. This evidence confirms the results presented in chapter 4 and strengthen the link between task characteristics, procedural coordination mechanisms and individual unit performance. While established by several studies in the case of contractual coordination mechanisms as highlighted by the meta-analysis presented in chapter 2, this link had not found any convincing demonstration yet in inter-organizational research.

These results were obtained considering both *client* and *server* relational activities. The different models estimated in this chapter, in fact, considered the impact both of relational activities directly initiated by the actors observed, and of relational activities in which the actors observed were involved, but which were initiated by someone else. The cases are quite different. In the first case, the strategic decision is about the activation of the tie, in the second case the strategic decision is about the acceptance of the proposed tie. Both type of networking activities, though, affected units' performance, showing an additional articulation of the relational space. The strategic domain of relational activities must include both *client* networking choices and *server* ones. While the former are intentionally initiated to achieve some result, the latter can be potentially as influential, but reproduce their effect in a mediated way through some kind of positive or negative spillover. It is interesting to note how, once again, the directionality of this effect depends on the nature of the task performed, with a trend equal to that of direct networking activities.

CHAPTER 7
Conclusions

7.1 Main findings of empirical work

The research presented in this thesis addressed two questions on inter-organizational relationships in the development of innovation: (1) what kind of impact do such relationships have on the partners involved, and (2) which processes account for these effects. To address these questions through the empirical analyses I introduced a theoretical framework to examine the structuring of inter-firm relations, distinguishing between contractual and procedural coordination mechanisms. Contractual coordination mechanisms identify all the arrangements used by the actors involved to determine the legal distribution of rights among the partners. Procedural coordination mechanisms identify all the arrangements used by the partners to exchange and combine the information needed to accomplish the joint tasks. The fit (or misfit) between the choices along these two dimensions and the characteristics of the task jointly performed determine the outcome of the relationship.

The strategy chosen to investigate these questions involved the combination of three different steps. First, a cumulative analysis of existing research to highlight supported findings and major unresolved issues. Second, a cross-sectional study on inter-organizational collaborations in new product development, focusing on individual relationships as the unit of analysis. Third, a network analysis of inter-organizational strategies in new product development and their implications for individual actors' performance.

The quantitative meta-analysis provided empirical evidence for the relevance of contractual coordination mechanisms. Their choice is strictly linked to the characteristics of the tasks performed within the relationship, and contributes to determine the relationship's outcome. Procedural coordination mechanisms, however, are rarely investigated and never in conjunction with choices along the contractual coordination dimension. Yet, they are theoretically considered by different perspectives as a fundamental element to be addressed within any relationship. The imbalance between theoretical propositions and empirical design weakens the findings about contractual coordination mechanisms, suggesting to desing a study simultaneously considering both contractual and procedural coordination mechanisms, and examining their impact on the relationship's outcome.

The study of 50 supplier-manufacturer relationships in new product development in the European major home appliance industry addresses these concerns. Using a ego-network design, it collects data on each relationship activated by a manufacturer (the ego) with all the suppliers involved in one specific new product development project (its network). For each single interaction, it operationalizes the theoretical constructs of contractual and procedural coordination, relates structuring decisions to the nature of joint problem solving activities, and articulates relationship's outcome from the manufacturer's perspective.

Contractual coordination is articulated focusing on the breadth (how many contingencies are specifically negotiated) and the specificity (the extent to which the arrangement is negotiated for a specific relationship or not) of the contractual arrangement. Procedural coordination is articulated by examining choices on timing of supplier's involvement, use of overlap vs. sequential approaches in joint problem solving, type of communication media used to exchange information, and frequency of information exchange among the partners. The empirical results show that, after controlling for procedural coordination mechanisms, contractual coordination mechanisms have only a limited impact on the outcome of the relationship. On the contrary, procedural coordination mechanisms explain most of the variance. Moreover, with different formulations of the outcome variable, similar choices along the structuring dimensions generate different results, depending on the characteristics of the joint problem solving. Higher investments in procedural coordination mechanisms are costly to set up and offer opportunities to pay back as long as they are used to nurture the manufacturer's knowledge base, rather than reduce internal development costs through sub-contracting. On the contrary, whenever short term efficiency is the goal of the interaction, suppliers should be given full responsibilities limiting the interactions with the manufacturer, and its investments in procedural coordination mechanisms.

These results are further explored in the third empirical study, holding contractual coordination mechanisms constant, and using network analysis techniques to articulate procedural coordination mechanisms in relational terms and examine their impact on actors' performance, focusing on 25 R&D units in the steel industry in 173 new product development projects during 1994. The unit of analysis (i.e. a single relationship) as well as the domain of interest (i.e. a new product development project) are kept constant in the design of this new study. Different data analysis techniques are chosen to overcome a shortcoming of analyzing relationships using traditional inferential statistics alone. It is fairly incomplete, in fact, to limit any analysis to a measure of the amount of activities performed with other actors. Without a specific investment focused on capturing the overall network of relations, we cannot discriminate any further among different relational strategies.

Depending on the characteristics of the task at hand, choices can be made not only with respect to the volume of the exchange, but also whether to rely on direct or indirect contacts, to invest on few strong ties or to be embedded in larger (but weaker) relational sets, to invest in the coordination of a more dispersed relation structure and narrow down the internal competencies to a limited domain, or rather divesify internally and selectively activate few complementary linkages. All these aspects are articulated adding to the concept of relational size (i.e. the amount of interactions activated by any given subject), the concepts of relational scope (i.e. the variance in the relational set of a single actor) and structural patterns (i.e. the chracteristics of the overall network in which actors are embedded). Relational size, scope and structural patterns are then related to the characteristics of the tasks jointly performed.

The intuitions behind the need for large investments in transactional activities to access external resources to solve complex problems find strong support in the empirical analysis. The evidence contributes to grounding empirically one of the pillars of knowledge-based perspectives of innovation processes. In addition to that, it also contributes to the theoretical debate showing the importance of consistency with respect to the unit of analysis used. Moreover, by widening the picture to include equivalent results with respect to characteristics of the relational sets activated and their interconnections, it shows how limited it is to focus only on some quantitative measures of exchange flows. On the contrary, the relationship between level of task complexity and relational scope and sub-groups structural patterns indicates the importance of the composition of relational sets.

Other things being equal -i.e. the possibility of activating external ties, the presence of reasources to invest internally etc.-, none of these decisions could be taken without carefully considering the type of joint work realized among the parties. Once more, the activation of external ties is not good or bad per se, but depends on the characteristics of the task at hand. More precisely, the ways on how to interact with other actors can be appropriately used to discriminate among possible alternatives using different leverages.

These results are further strengthened by using network regression models to assess the impact of different relational strategies on individual actors' outcome, considering both *client* and *server* networking activities, and evaluating the role of task characteristics. *Client* networking activities identify all the relationships activated by the actors to accomplish tasks under their own responsibility. *Server* networking activities identify all the relationships in which the actors are involved by others, because of their distinctive competencies and resources. In the first case, the focus is on actors decisions on "buying" external resources. In the second case, the focus is on actors decisions on selling internal resources. Both decisions jointly determine the overall strategic networking domain and have to be considered to assess its implications on individual actors' outcome.

The econometric derivation of models including a network representation of relational activities show the importance and the implications of an examination of such activities going beyond attributional indicators. By using a matrix representation of inter-actor ties I include at the same time relational size, scope, and structural patterns, distinguishing between *client* and *server* relationships. The empirical analysis confirms the presence of both network effects, linking statistically actors' performance to the characteristics of relational activities. Higher levels of task complexity are associated with a positive impact on individual units performance, while lower levels of task complexity are associated with a negative one.

The implications of investing in relational activities are therefore confirmed to be contingent upon the characteristics of the tasks performed within the relations. The decision of activating external ties is not going to affect positively or negatively the outcome of the actors involved per se. On the contrary, it strongly depends on the characteristics of the activities jointly performed and on the congruence between them and choices of the structural arrangements to govern the relationship.

7.2 Theoretical contributions

This research offers several theoretical contributions to the analysis of inter-organizational relationships in the development of innovations. The first contribution of the dissertation is the recomposition of institutional decisions driving the governance of inter-firm relations and their organizational implementation. By building on previous works in economics, strategy and organizational design, the framework developed in chapter 2 considers as fundamental elements for the effectiveness of inter-firm relations both status variables (i.e. determinants of cooperation) and process variables (i.e. procedural mechanisms to coordinate the relation). It links inter-organizational structures to the nature of the task being performed and articulates such structures into contractual and procedural coordination mechanisms. Moreover, by explicitly including organizational design constructs as moderators of the impact of inter-firm relations on the final outcome it extends the contingency approach from the intra-organizational domain to the inter-organizational domain. Not only would such an effort provide normative indications of the impact of different structuring choices on the outcome of the relations, but it would also be the basis for a theoretical assessment of inter-organizational structures.

The second contribution lays in the use the relationship as the unit of analysis, within one specific activity: the development of a new product. Usually, the selection of multiple activities is driven by the implicit assumption of within-activity homogeneity with respect to the chosen attributes (e.g. uncertainty). I contend that we can observe variance within the same type of activities and that such variance should also correspond to differences in their organization. Lawrence and Lorsch (1967) idea that sub-units within the same organization are structured differently is therefore extended to the activity level, claiming that the same activity can be organized differently even within the same unit. This approach enriches the framework with the results of the literature on innovation management when several taxonomies of innovation are proposed to be related to different organizational solutions. In addition to that, it helps in setting the boundaries of inter-firm contributions. For example, if the purpose of the development project is the rejuvenation of an already existing product, suppliers' participation might be limited to meeting slightly modified engineering specifications. In contrast, substantial changes in the existing product base might require the design of completely new components. The differences in the activity observed (the development of new products) should therefore correspond to differences in inter-organizational choices.

The third theoretical contribution is the conceptual modeling of structuring alternatives using a relational perspective. While interested in the analysis of specific relationship, previous studies have only indirectly derived information and provided implications on the basis of attributional analysis focusing on inter-subject differences, rather than inter-relational differences. Departing from this well established tradition, the studies presented in this dissertation stress the conceptual salience and empirical relevance of choosing the appropriate unit of analysis whenever approaching the study of inter-organizational relations. The concepts of network size, scope and structural patterns are developed to model behavioral explanations for sources of organizational inertia in innovative processes and their econometric specification in network autocorrelation models provides the basis for formal tests of contextual effects on individual actions.

Finally, this dissertation offers a distinct set of contributions from a methodological perspective. First, it combines within the same research project both qualitative and quantitative methodologies, stressing the importance of coherence between research question and research method over a simplistic and ideological preference for either the deepness of qualitative data or the richness of quantitative data. Second, it presents a quantitative meta-analysis using studies not based on experimental or quasi-experimental designs, discussing the inherent difficulties associated with these types of analysis and offering some practical solutions. Third, it designs and develops the use of network analysis techniques not simply descriptively, but also inferentially.

7.3 Managerial implications

These theoretical aspects have direct managerial implications with respect to the consideration of the strategic impact of relational activities. First, planning and implementing ties and connections with other actors goes well beyond the definition of the contractual coordination mechanisms chosen to govern the relation. Although frequently considered as a fundamental aspect for the governance of the relationship, the definition of the legal boundaries of the agreement are not sufficient to obtain the desired outcome. External conditions such as local systems of norms and practices might even question the necessity of specific investments in the contractual coordination side. While still a key component of the decisions over alternative structuring arrangements of inter-organizational relations, these results suggests not to overlook the procedural coordination side by placing an excessive emphasis on the contractual coordination side, at the expenses of the final outcome of the relation.

Second, the impact on the performance of the actors is strictly linked with the structuring decision taken with respect to the procedural coordination mechanisms used to make the relationship work. While still controversial from the results of the meta-analysis presented in chapter 2, the effect of alternative choices on how to implement the exchange among the parties which emerges strongly from the different field studies attracts managers attention to the relevance of inter-organizational structuring decisions.

Third, and closely related to the previous point, the choice of procedural coordination mechanisms cannot rely simply on traditional perspectives of organization structuring, but can usefully be extended to include a relational perspective. In defining the possible mechanisms available to realize some kind of exchange with other actors, managers can use the concepts of network size, scope, *client* and *server* contacts to structure not only one single relation, but their whole relational set. Traditional organization design variables need to be considered in a relational perspective. Communication channels, for example, can be considered by design as the way through which the overall information set accessible is defined. The combination of different resources to innovate can therefore be realized not only by combining individuals selected on the basis of some demographics (ex. multi-functional teams), but designing ex-ante opportunities for contamination and resource exchange with other units through a varied relational set and multi-contextual opportunities of interaction.

Similar structures, however, might be economically justified only in certain cases, considering the coordination costs associated with more articulated relational structures. Indeed, the empirical results show that investments in relational activities need to be congruent with the type of task jointly performed, in order to pay back. Depending on the characteristics of the task at hand, therefore, different procedural coordination mechanisms can have very different impact on the outcome of the subjects involved. On the one hand, a pure financial evaluation based on short term observations of such impact might underestimate the effect deriving from changes in the competence set which need longer time spans to become visible. On the other hand, leaner structures might generate a positive impact on the overall cost structure of the focal firm, but could not be exploited to affect its competence base. Differences in the observed outcome of different procedural coordination mechanisms reflect their appropriateness to achieve different outcomes. Investments in dense and differentiated relational arrangements are certainly increasing the opportunities for exchanges, but so are the related costs. Depending on the expected outcome, therefore, the choice of the corresponding set of procedural coordination mechanisms should be made accordingly.

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