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SUPPLIER-BUYER NETWORKS AND BUYER'S INNOVATION

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To my family, my brother-in-law Paolo, and to Valerio
with infinite gratitude for reasons they know well

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CHAPTER I - INTRODUCTION

1.1 Research problem

Research has shown that innovation is an interactive, cumulative and cooperative phenomenon occurring between different actors (Burt, 2004; Powell et al., 1996; Ahuja, 2000; Zaheer & Bell, 2005; Pittaway, 2004). Single organizations often do not possess all the knowledge needed to undertake innovation internally and need to mobilize external actors in new product development, namely firms that have different knowledge bases. Vertical relationships are characterized by complementarity in the partners' knowledge bases (Najmaei & Sadeghinejad, 2009).

As innovation is a focal point of industrial competition, "deconstructed" firms are emerging. In order to compete, firms are developing cooperative networks of vertical relationships with their suppliers to leverage their resources (Campbell & Wilson, 1995). Coordinated relationships to provide value chain activities and innovation are widespread. In fact the progressive erosion of corporate boundaries can be traced back to two main forces: the diffusion of flexible specialization, resulting in a high degree of productive decentralization, and the need for accelerating organizational learning, given its connection with corporate survival (Lomi, 1997). In a context in which rebuilding value chains is becoming a fundamental strategic tool, the attention to vertical relationships is of ever greater significance.

The primary aim of my research is to explore the effects of a firm's network of vertical relationships on innovation; in particular, the focus is on the causal relation between a *buyer's innovation output* and a *supplier's network* (with buyers and suppliers). The addressed research problem investigates whether and how the *characteristics of the supplier's network affect the buyer's innovation output*. Starting from a focal buyer firm, I consider its relationships with suppliers and how these suppliers' networks of ties affect the focal buyer's innovation. This perspective aims to open a novel pathway in social network literature, since prior research in the field has focused mainly on the effect of horizontal collaborative relationships on firm innovation.

The dissertation is focused mainly on indirect relationships, highlighting the role of the nodes indirectly linked to the firm and assessing their effects on the firm's innovative performance. According to Burt (1992), selecting alters with many other partners is one mechanism by which an actor can develop an effective network. However, I will propose a limitation to this argument, underlining that a *contingent approach* is needed to evaluate the benefits of indirect ties; this is particularly true when studying vertical relationships.

Researches have stressed the importance of structure, undervaluing other dimensions for knowledge-sharing. The principle underlying the contingencies I will consider is that generation and appropriability are two separate issues for innovation output. The value the firm gets from its contacts depends on the resources of these contacts and on the ability to exploit these resources. I will introduce the following contingency factors to address the problem: (i) the type of actors involved in indirect ties (their role in the supply chain: suppliers or other buyers); (ii) the strength of relationships (measured in terms of level of collaboration: arm's length ties, alliances, arm's length ties plus alliances).

Accordingly, I examine two research questions: (1) *What effect does supplier's centrality in its network of buyers and suppliers have on buyer's innovation output?* (2) *What is the effect of the strength of the ties in the supplier's network on buyer's innovation output?* In order to answer these, I draw upon constructs like centrality, multiplexity, competition, cooperation. In this way, I aim to analyze the network structure and the type of relations.

The hypotheses are built around the principle that indirect ties can be both beneficial for greater knowledge opportunities and detrimental for the competition among nodes that are indirectly linked. Consequently, we expect a final positive effect when both knowledge opportunities are raised and competition is lowered and a negative effect in the opposite conditions. To get innovation from the network, the buyer needs: effective transfer of knowledge, cooperative efforts, increased availability of different information resources for idea generation, reduction of knowledge spillovers from the focal buyer to external actors.

The research highlights distinct dynamics of knowledge flow involving the firm and its suppliers and competitors, distinguishing between the collaborative and competitive dimension of a supplier-buyer network. In most industries, competition and collaboration at all the levels of the supply chain replace a situation in which the supply chain was a single entity competing with other supply chains. This increases the relevance of the research. The introduction of the competition issue is an element of novelty because competitive dynamics are often under-examined in the social network literature in favor of collaborative dynamics. Many researches have focused on the relationship between strategic alliance networks and innovative outputs, but these works largely spotlight the effects of technology-based network ties among competitor firms (Owen-Smith & Powell, 2004).

The theoretical framework revolves around the mechanisms of inflow and outflow of knowledge in the presence of indirect ties and supplier-mediated competition and collaboration. First, I try to identify the supplier's network characteristics that facilitate the positive leakiness and positive stickiness for the focal buyer and consequently spur the buyer's innovation output. As Bengtsson and Ericsson (2002) argue, there is a flow between an innovation project and the context that can be characterised by "leakiness" and "stickiness". Both can be positive or negative. Leakiness is the easy flow of knowledge and resources: the positive one is into the project, the negative one is out of it. Firms need to protect themselves against negative leakiness. Stickiness is the "mechanisms that hinder the flow". The positive one protects ideas from spreading to competitors. The negative one is the hindering of the flow among partners. Ties are conduits of knowledge: more ideas for the focal actor but also knowledge spillovers for alters. Second, I try to find some criteria (supplier's networks characteristics) to determine ex ante to what extent a focal buyer will benefit from a variable game structure of supplier-mediated competition/cooperation. We deal with competition among buyers who have the same supplier. The supplier has the role of a broker, through which proprietary knowledge can potentially flow. Buyers compete for the use of innovation that is often exclusive (problems of protection of Intellectual Property Rights). At the same time, they indirectly cooperate because they contribute to the building of a common knowledge base and competences of the supplier. Some of the development achieved in a project can be redeployed in other projects. A supplier-buyer tie favors innovation generation but creates a problem of appropriability of innovation. The focus is on not just creating but capturing value.

These topics have been under-examined in the existing literature. Takeishi (2001) argues that competing firms may share some partners and each firm still has to compete with other firms who are seeking similar relations with the firm's capable partners. Therefore she aims to answer the question: "How could a company outperform competitors who also have cooperative relations with their partners?". She adopts a perspective of division of labor with the supplier, analyzing how some automakers manage more effectively than others the division of labor with suppliers who play critical roles in automobile product development. I aim to bring the supplier's network characteristics into the picture.

The tension between competition and cooperation is particularly stressed in multiplex networks (Shipilov & Li, 2010), structures including firms playing different roles and linked through different kinds of relationships. My hypotheses are formulated on a multiplex network, considering also the addition of other relationships to a supply tie. In fact, beyond selling goods, a supplier may have another type of linkage: a strategic alliance (related to different functions such as R&D, marketing, etc.). Multiplexity in dyads is defined as a structural property occurring when the two parties involved in a tie have more than one kind of relationship with each other (Wasserman and Faust, 1994). More generally, the definition of a multiplex network is an extension of the dyadic definition of multiplexity, meaning that the network's members are linked through different kinds of relationships (Shipilov & Li, 2010). For example, two nodes are linked by an alliance, while two other nodes are linked by a supply tie.

For theoretical clarity, in this work I focus mainly on vertical relationships, which I define as relationships occurring between two firms located at a different level of the value chain: a supplier and a buyer. Vertical ties involve companies that operate at two subsequent stages within the same production process (Dussauge, Garrette & Mitchell, 2000, 2004). The suppliers considered are firms whose core business is to supply components, not firms at the same level of the value chain of buyers, which could be also competitors. The specificities of networks of vertical ties consist in the flow of complementary information and the frequent pre-existence of an intrinsic tie, that of supply, so that there are cases in which any other form of relationship is in addition to that one. Usually buyer-supplier ties can have different contractual arrangements with a range of variation from arm's length market contracting to alliances (with high trust and long term exchange) (Meehan & Wright, 2011). I consider these kinds of relationship: (a) a supply tie that a firm takes up for the procurement of components, (b) an alliance, a collaborative agreement (specifically: R&D alliances, manufacturing alliances, supply collaborative agreements, licensing agreements, cross-licensing agreements), (c) a supply tie and an alliance combined. I define a supply tie or arm's length relationship as: a relationship based on short term, discrete supply (Parker & Hartley, 1997) on the open-market, in which the primary focus is to achieve cost reductions or maintain profit margins often at the expense of the other party (Soonhong & Mentzer, 2000). I define a vertical alliance as: a voluntary arrangement between a supplier and buyer implying joint involvement in product development, co-makership, sharing of resources. It is a relationship characterized by continuity between two independent firms operating at successive stages in a vertical chain of production, with both firms expecting the interaction to continue into the future (Heide & John, 1990) in a long time horizon. This kind of tie is an intermediate solution between the two extremes for organizing vertical relationships: *make* (vertical integration) and *buy* (arm's length tie), explained by TCE (Coase, 1937; Williamson, 1975). It is interesting to examine better the effects of this "hybrid" form of organization (Gulati et al., 2005) because this governance structure has varying expanses of vertical and horizontal control (Joskow, 2003).

The weakest relationship is a supply tie, then a stronger one is the alliance, and the strongest one is the alliance plus supply, having a multiplexity context. In this respect, one significant conclusion is that when companies compete for information, strong ties win. This is a limitation to Granovetter's (1973) argument of the strength of weak ties. I will show the difference in the impact of the strength of the ties in a collaborative context and in a competitive context.

1.2 Theoretical motivations

The topic is at the confluence of two lines of research: *network theory* and *supplier-buyer relationships literature*. The theoretical contribution derives from the combination and extension of these. In this paragraph I briefly explain these two points.

Network theory is extended through the introduction of a contingent approach to evaluate the benefits of indirect ties. This is particularly useful when studying vertical relationships. The commonly acknowledged conclusion that selecting alters with many other partners is a good mechanism to follow is called into question. It turns out that the type of actors involved in the indirect ties is the discriminating factor. Moreover, network theory scholars have not agreed on the most beneficial structure for innovation. There is a trade-off between closed/disconnected network structures that favor idea implementation/generation. I try to investigate the role of brokerage in a cooperative and competitive context, underlining also the importance of the way in which the broker is connected to the different extreme nodes with weak or strong ties, and its impact on idea implementation. The study contributes to the debate on the trade-off between strong and weak ties taking place among network scholars: the effects of the strength of ties (depending on the type of tie) on the innovation output are shown to be contingent on the context (e.g. competition for information). I also try to extend *network theory*, following the emerging need in social network analysis to enrich the simple network models with more complex modeling constructs in order to carry out more accurate analyses of the real world. Multiple kinds of edges and nodes are being simultaneously analyzed.

Supplier-buyer relationships literature is extended with the shift from suppliers' firm-level characteristics to network-level characteristics for supplier selection and the concept of the supplier as a strategic broker. *Supplier-buyer relationships* literature has been mainly dyadic in focus and has ascribed conflicting effects on innovation to suppliers' firm-level characteristics. It would be interesting to study more extensive supplier-buyer networks. Scholars linked to the IMP (Industrial Marketing and Purchasing) group have advocated this need but there is still a lack of an effective application. I aim to apply a wider network focus and to introduce network-level characteristics for supplier selection. The supplier is likely to be a gatekeeper (opening the access to the external environment) and knowledge broker (spanning the holes between the focal buyer and its other buyers/suppliers that typically have disconnected pools of information). The concept of the supplier as a strategic broker helps to deepen the structural holes theory. Evaluating a supplier just on the basis of its internal resources is a shortsighted attitude, and we should include the analysis of its connections. Two elements seem interesting here: the inflow and outflow of knowledge passing through this actor and supplier's active role in shaping competition/ cooperation. It can be useful to figure out how this role can change on the basis of some attributes of the relationships and of the actors composing the network of vertical ties.

On the other hand, the work is a theoretical contribution also because it bridges the two above-mentioned theories. Bridging them is useful to integrate the concepts of *relational embeddedness* (studied in supplier-buyer relationships literature) and *structural embeddedness* (prevalent in network theory) in a single framework. While *relational embeddedness* stresses the role of direct cohesive ties, referring to the dyadic specific quality of social capital and to the nature of the relation (e.g. strong/weak ties), s*tructural embeddedness* shifts the analytical approach to the system, focusing on the position that a firm has in the network's overall structure. The focus is also on indirect ties: resources developed in a direct relationship have implications for resources available to actors involved in indirect relationships. In this way, I can figure out the advantages derived both from the position in the network and from the characteristics of the individual relationships.

This combined perspective is particularly useful in the context of vertical ties, more than in the context of horizontal ties, for at least two reasons. Firstly, *structural embeddedness* and the consequent focus on indirect ties is important in a network of vertical ties because the nodes involved in direct and indirect ties are expected to have different roles (i.e. a buyer is directly linked to a supplier and indirectly linked to a buyer or to a supplier), while in horizontal ties they should be similar (i.e. a firm is directly linked to a competitor and indirectly linked to another competitor). When considering the whole network, the heterogeneity of actors in the value chain opens interesting avenues on issues like mediated competition (the location within the network shapes competition) or complementarity of knowledge flowing in the network. Secondly, it is likely to find high variance in the type of *relational embeddedness* in a network of vertical ties. Even considering a single tie, there is often at least one form of relationship: the supply tie. Other kinds of relationships can be added to that one. Supply agreements may be supported by exchanges of technological know how, personel or equipment. In this case, supply ties are likely to generate ties in different networks (Lomi & Pattison, 2006). The different roles of the nodes in the value chain further strengthen this variance. Firms can be connected through multiple types of connections each of which could be a social network. It could be interesting to focus on more than one network at a time.

To bridge the two streams of literature means also to merge the theoretical foundations on which they rely: *social capital theory* and *transaction costs economics* (TCE). *Social capital theory* emphasizes collaboration and knowledge sharing. The assumption of social capital theory is that a network provides value to its nodes by allowing them access to the social resources that are embedded within the network. Nahapiet and Ghoshal (1998) argue that “Who you know affects what you know”. The resources in social capital can reduce the time and investments needed to gather information (Zhang, Cavusgil & Roath, 2003), stimulate a firm’s intellectual potential, and support “knowledge-creating organizations” (Nonaka & Takeuchi, 1995). Social capital theory is considered an important perspective for theorizing the nature of connection and cooperation between organizations (Adler & Kwon, 2002). In particular, there are three dimensions of social capital: (1) the relational dimension (trust, identification and obligation); (2) the cognitive dimension (shared ambition, vision and values); and (3) the structural dimension (strength and number of ties among actors) (Nahapiet & Ghoshal, 1998). I try to take into consideration all the dimensions because I examine both the network structure and the quality of the relationships. Implicitly I try to figure out what is the effect of these dimensions of social capital on the buyer's innovation. While social capital theory emphasizes reciprocity and trust, *transaction costs economics* (TCE), emphasizes opportunistic appropriation, asset specificity and its protection, bounded rationality, and attributes to enforce agreements. Transaction costs are the direct costs of monitoring and enforcing contingent contracts as well as costs related to ex ante investments and ex post performance inefficiencies. To undertake transactions means to face a variety of potential transaction costs, contractual and organizational hazards linked to the attributes of the transaction (asset specificity, complexity, uncertainty, conflicting interests, etc.) and their interplay with the attributes of alternative governance arrangements (Joskow, 2003). By considering multiple types of ties of different strength in this thesis, I take into account the TCE principle that the level of collaboration within the supply chain may vary from transactional to more relational collaborations. The main conclusion of TCE, useful for my theory building, is that in order to protect transaction-specific assets from opportunistic appropriation, firms will choose to increase the extent of hierarchical control over the other party in the relationship. The "hybrid" organizational form is the solution between make and buy options.

Moreover, when adding a network context it is interesting to note that transaction costs for a node are also a function of the attributes of the other transactions of its partners. The incentive a partner has to behave opportunistically is dependent on the opportunities or constraints it experiences in the transactions with its other partners. The likelihood of breaking a contract or violating common rules is a function of the benefits the actor can get not only in the specific relationship but in the set of relationships with all its partners. In this wider context, also useful is the TCE conclusion that the less the competition, the more likely is the exposure to a small amount of bargaining and opportunistic behavior.

In sum, the interplay of these two perspectives (social capital theory and TCE) in the study of supply relationships provides new insights on the drivers of actors' behavior and payoff, focusing both on knowledge sharing and opportunistic threat. In particular, it boosts the simultaneous analysis of the determinants of cooperation and competition and their relation with innovation. While cooperation spurs invention, competition hampers innovation.

In building the theory, in fact, I must take into consideration the distinction between invention and innovation. Invention or generation of innovation is the development of a new idea or an act of creation. I should figure out how the network structure and content (the actors, the kinds of relationships, the positions of nodes) affect invention through the availability of resources. Innovation refers more to the commercialization of the invention (Hitt, Hoskisson & Nixon, 1993; Schumpeter, 1934). In this study I also deal with this final stage, therefore I am forced to consider competition to innovate, that is, patent race. I want to explore how the suppliers' network of ties, together with the cooperative and competitive dynamics that it creates, affects the focal buyer's innovation.

1.3 Overview and structure of the research

In order to test the hypotheses, I assume a network perspective with a focus on knowledge transfer in order to understand the flow of knowledge through the different kinds of ties. The sample is built from a directory listing all the North American suppliers of motor vehicle firms, the ELM Guide, analyzed in five years: 1994, 1996, 1998, 2001, 2004. I was able to build the supply network for each year in order to link the relations of the supplier with the innovative performance of the buyers. In each year I found approximately a thousand nodes. For each supplier the directory provides the list of all the customers, which can be motor vehicle companies or other suppliers. Then I was able to build the alliance network. I looked for all the alliances of the nodes using the SDC Platinum program and I matched the partners present in the alliances with my original sample in order to keep alliances involving at least two nodes present in my sample. Finally, I merged the supply and alliance networks to find a multiplex network, representing both kinds of relationships. In this way I was able to establish the strength of the relationship (scoring the different kinds of relationships).

The supplier's centrality among other suppliers and among buyers is regressed against innovation performance, measured as the patents count of the buyer. This shows that the type of node matters. Also, the strength of ties is introduced in the model, showing that the strength of the relation matters. The dissertation is articulated as follows.

In the following Chapter (II) a review of the literature is presented. I refer to network theory, supplier-buyer relationships literature, transaction costs economics, and literature on competition and cooperation. I identify the fundamental principles and results of these streams of research and I underline the main gaps that can be filled and that are the foundations for my attempt to extend or enrich these lines of research.

Chapter III presents the hypotheses development. I focus on the importance of the structural characteristics of suppliers' networks and on the distinct effect of different kinds of nodes indirectly linked to the buyer (other buyers or suppliers). I introduce the role of the strength of the tie as a moderating factor influencing the impact of centrality on the innovative output.

Chapter IV presents the research design. I describe the empirical setting and explain in detail the process of data collection and elaboration. Also, I introduce the variable definition and operationalization referring to the statistical model implemented and explain the statistical model chosen.

The work ends with the illustration of the results of the analysis and of some robustness checks in Chapter V. I report the outcome of the regression. I also include discussion and conclusions, about the main contributions to theory and managerial practice, together with limitations and directions for further research.

CHAPTER II - Conceptual Framework and Literature

This chapter illustrates the theoretical foundations of the present study. The topic is mainly at the confluence of two lines of research, *network theory* and *supplier-buyer relationships literature* and relies on some conceptual frameworks provided by other theories, in particular *transaction costs economics*. The latter is fundamental in the analysis of vertical ties and in the choice of the different kinds of inter-organizational relationships in a setting like this.

I refer to *network theory*, focusing on the part of this literature that is related more to knowledge transfer through collaboration (social capital theory) and innovation output. I refer to *supplier-buyer relationships literature*, considering in particular the studies on supplier involvement in new product development, with a focus on the supplier's characteristics that are considered as a driver for the buyer's innovation output. Finally, I refer to the *transaction costs economics* perspective to deepen the knowledge of the characteristics of buyer-supplier ties.

The bridge of the above-mentioned theories is useful: (1) to integrate in a single framework the concepts of relational embeddedness and structural embeddedness in a context of vertical ties and (2) to merge the theoretical foundations of *social capital theory* and *transaction costs economics*. The interplay of these perspectives in the study of supply relationships provides new insights on the drivers of actors' payoff. This is because it allows us to focus on both knowledge sharing and opportunistic threat.

The literature on competition and the trade-off between competition and cooperation then naturally comes into the process. I will also refer to this stream of research. While much of the tradition in research has focused on the dynamics of competition, scholars in the last few decades have increasingly redirected their interest to aspects of cooperative behavior, looking at the increasing trend of firms entering into cooperative ties with each other. However, the sociological approach has overemphasized this aspect. My aim is to try to bring the competitive side of the context into the cooperative picture. Collaboration implies mutual adjustment needed for the exploitation of complementary resources but sometimes there is both collaboration and conflict of interest, rivalry or even outright competition (Nooteboom, 2004). This tension between collaboration and conflict of interest is stressed in the hypotheses development of this thesis.

2.1 Different views on the inter-organizational network phenomenon

In recent times many industries have seen the rise of stable business networks and cooperative arrangements (see for instance Contractor & Lorange, 1988; Ohmae, 1989; Alter & Hage, 1993; Jarillo, 1993; Mitchell & Singh, 1996). This phenomenon has been interpreted through different theoretical lenses. I briefly mention them.

The traditional economic approach views networks as a form of organization through which assets are allocated and transactions are governed. Basically, it is proposed as an alternative organizational form to markets and hierarchies for governing exchanges. In this view, cooperative arrangements occur when transaction costs associated with a specific exchange are too high for an arm's length market exchange but not high enough to mandate vertical integration (Hennart, 1988). For a given resource or transaction, the appropriateness of each ownership solution or governance structure is estimated at a given point in time in order to adopt the optimal one.

Prominent schools of thought in this respect are transaction cost economics (Williamson, 1975, 1985, 1991; Williamson & Ouchi, 1981; Powell, 1990; Powell & Smith-Doerr, 1994), agency theory (Jensen & Meckling, 1976; Fama, 1980), and the property rights approach (Grossman & Hart, 1986; Hart and Moore, 1990; Holmstrom & Roberts, 1998). Among these approaches, the prevailing assumption seems to be that individuals and firms tend not to comply with agreements and act opportunistically. Inter-firm relationships are considered a result of market failure. This demonstrates the basically negative perception of the network phenomenon held by these schools of thought. Moreover, they often deny the possibility that relationships will survive a long time, arguing that hybrid governance structures are temporary organizational forms that will eventually be replaced by a hierarchy or marker relationship.

However, the phenomenon we have witnessed since the end of the 1980s cannot be explained solely through power or cost aspects on behalf of a single party (Jarillo, 1988). There must be a win-win character to these relationships for the parties involved (Pilorusso, 1997; Dyer & Singh, 1998). In fact, network theories are used to explain lasting inter-firm relationships from a positive systemic viewpoint. Also, RBV (Wernerfelt, 1984; Barney, 1991) holds a more positive view with regard to business networks. However, the primary unit of analysis of the RBV is the individual firm and its focus is on those resources that the firm itself possesses (Dyer & Singh, 1998). The network approach, instead, considers the collection of firms that make up inter-firm networks and inter-firm relationships as the unit of analysis as such (see, for example, Evan, 1966, 1972, 1974). The question becomes: “in which environmental contexts and processes are inter-firm relationships and interactions embedded?” (Kamp, 2007). Firms are first of all viewed as interdependent, in spite of their legal autonomy, and involved in cooperative interactions. Network theory focuses on the exchange relationship and the inter-firm dynamics of alignment of complementary assets, resources and activities (Hakansson, 1982, 1987, 1989; Johanson & Mattsson, 1987, 1991; Hakansson & Johanson, 1988; Hakansson & Shehota, 1995; Laage-Hellman, 1997).

The aim here is to integrate both views in a single framework and try to figure out which is the pay-off of an actor in a network, given that both positive and potential negative effects of the relationships are simultaneously in place. Scholars of corporate strategy have suggested that firms enter cooperative relationships to improve their strategic positions (Porter & Fuller, 1986; Contractor & Lorange, l988; Kogut, 1988). Hence, in the end, I will figure out which network structure is the most beneficial for the ego-strategic competitive advantage.

2.2 Network literature and innovation

2.2.1 Review

Economic sociologists define a network as a form of organized economic activity that involves a set of nodes (e.g. individuals or organizations) linked by a set of relationships (Granovetter, 1973). These can include, for instance, supplier relationships (e.g. Dyer, 2000), interlocking directorates (e.g. Davis, 1991), relationships among individual employees (e.g. Burt, 2004), or strategic alliances (e.g. Gulati, 1998). The distinctiveness of the social network approach consists in the focus on relations among actors, in the ability to address multi-level issues, and in the integration of quantitative, qualitative and graphical data.

In the past few decades there has been a huge upsurge of interest in the role of networks, even if no one was quite sure whether networks were a metaphor, a method or a theory (Barnes, 1972). However, looking over the existing works in social networks we can find three categories of research: (i) theories borrowed from other disciplines such as mathematics (graph theory) and social psychology (balance theory and social comparison theory). As a consequence, one of the attractive features of the social network approach is the potential to analyze network relations with an expanding range of algorithms, programs and procedures that map strategic and behavioral patterns; (ii) applications of network ideas into existing organizational theories; these make the boundaries of the topic very flexible. I will focus my attention on some of them later on in the paragraph; (iii) indigenous social network theories, which I will briefly analyze here.

The general theoretical basis of the network approach is to have provided a fruitful micro-macro bridge: small-scale interactions become translated into large-scale patterns, and these in turn feed back into small groups (Granovetter, 1973). This allows researchers to capture the interactions of any individual unit with the larger field of activity to which it belongs. Organizations are no longer considered atomistic entities, but actors whose economic actions and performance are influenced by the context, by the network of inter-organizational relations in which they are embedded. Inter-organizational ties have an important role in shaping firm behavior and outcomes.

Most writings recognize that *embeddedness*[1] in a network as a strategic resource has a relational as well as a structural dimension. *Relational embeddedness* stresses the role of direct cohesive ties, referring to the dyadic specific quality of social capital (strong/weak ties), and reflecting the nature of the social ties between dyads (Granovetter, 1973). S*tructural embeddedness* shifts the analytical approach to the system, focusing on the position that a firm has in the overall network structure. It highlights the advantage a node can derive from its position in the network rather than the advantage from individual relationships (Granovetter, 1992; Gulati, 1998; Nahapiet & Ghoshal, 1998).

The distinction between these two dimensions corresponds to a general distinction between two streams of works in network research. I refer to researches adopting a structuralist vs a connectionist perspective (Borgatti & Foster, 2003). This distinction is also underlined in different terms referring to the distinction between the positional vs relational perspective (Burt, 1982).

[1] Defined as the "economic action that is affected by actors' dyadic relationships and by the structure of the overall network of relations" (Granovetter, 1985).

(a) The structuralist perspective

The structuralist perspective focuses on the structural configuration of the ties. It makes predictions concerning how actors in networks influence each other's attitudes and behaviors. It concludes that an actor's payoff is a function of network structure and of its position in the network.

Structural role theory includes the concepts of structural equivalence, structural cohesion and role equivalence. *Structural cohesion* refers to the fact that nodes are constrained by the structure of a cohesive group in which they are embedded (Friedkin, 1998, 1984). The clique is the typical form for the structural cohesion; one actor's behavior is influenced by the behavior of the closely tied actors. Two nodes are *structurally equivalent* if they are connected with the same tie to the same third party (Lorrain & White, 1971). The theory forecasts similar outcomes for nodes that occupy structurally equivalent positions. Burt (1987) suggests that structurally equivalent nodes recognize each other as comparable and in competition and imitate aspects of each other to have advantages with the third party. Organizations occupying similar network positions are frequently portrayed as sharing the same structural interests (Pallotti & Lomi, 2011). The concept of imitation is further developed by Di Maggio and Powell (1983), analyzing organizational isomorphism. Two nodes are *role equivalent* if they occupy similar structural positions but in different networks (Krackhardt & Porter, 1986).

The basic assumption in this stream of network research is that networks, shaping the actor's background for action, provide opportunities and constraints on behavior. Hence, studies that examine the consequences of networks, more than their antecedents, are typically consistent with the structuralist perspective. The causes of the formation of ties, by contrast, are better suited to a sociological approach.

Several works have focused on the benefits for a single actor in the form of the so-called *structural capital*. The proposition that an actor's position in a network has consequences for the actor, so that the actor can exploit its position in the network to maximize gain, is the structuralist paradigm proposed by Blau (1977) and Mayhew (1980) and expressed in the network context by Wellman (1988). It is centered mainly on the concept of power and influence.

The most recognized and well known results in the network studies relate to the benefits to actors of occupying central positions in the network (Brass & Burkhardt, 1993; Powell et al.,

1996) or having an ego-network with a certain structure (Burt, 1992, 1997; Burt, Hogarth & Michaud, 2000; Coleman, 1990), for instance sparse or dense. The motivation behind the benefits is mainly the possibility to exert power and influence on the other nodes and to be in a position of independence. Studies have looked at both relations in the direct ties and indirect ties. The linkages between a node's indirect contacts matter: for instance, being in the shortest path between unconnected actors can be positive. The effects were studied also at the network level, relating the structure of a group to its performance (Athanassiou & Nigh, 1999), as in the case of a study assessing the connection between centralization of the network and group performance (Bavelas, 1950).

(b) The connectionist perspective: networks, resources and knowledge flow

On the other hand, the connectionist approach looks at the interpersonal transmission process occurring in social ties using micro-mechanisms. It focuses on the content of the relationship. It emphasizes the resources that flow through it (Stinchcombe, 1990; Gulati, 1999).

Sociologists began to dominate network research in the 1970s, but Granovetter (1985) was the first one who brought into the picture the sociological perspective, looking at economic ties no longer as transactions but as relationships. Following his study, a lot of researches suggested that firms, as well as individuals, develop embedded ties characterized by trust and rich information exchange across organizational boundaries (Eccles, 1981; Useem, 1982; Dore, 1983; Powell, 1990; Uzzi, 1997; Zaheer, McEvily & Perrone, 1998; Dyer & Chu, 2000). Rodan and Galunic's (2004) findings suggest that, while network structure matters, network content that flows in the network is of equal importance for innovation performance. Ties are basically conduits for information and resources (Lin, 2001; Snijders, 1999; Atkin, 1974); networks, whether operationalized in terms of informal or formal ties, channel and direct flows of information and resources from position to position within a social structure (Owen-Smith & Powell, 2004).

In fact, inter-firm collaborative linkages can be generally associated with two kinds of network benefits. The first is resource sharing: the combination of knowledge, skills, and physical assets among firms; the second is knowledge spillovers: information conduits through which news of technical breakthroughs, and new insights into problems flow (Ahuja, 2000). The first one allows the transfer of deep knowledge and material resources and is typical of direct ties, the second one of information, and is typical of indirect ties (Kogut & Zander, 1992; Ahuja, 2000).

Therefore from this perspective, the benefit for the actor in the network resides mainly not in structural capital (meaning mainly power and influence) but in social capital. Probably social capital theory is the biggest growth area in organizational network research; it is to a great extent derived from social support literature (Walker, Wasserman &Wellman, 1994) and social resource theory (Lin, 1982, 1988), and it has helped to fuel interest in social networks. The concept of social capital is defined as "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit" (Nahapiet & Ghoshal, 1998).

Consequently, the actor's benefit is a function of the quality and quantity of resources controlled by the actor's alters (Anand & Khanna, 2000; Koka & Prescott, 2002; Oliver, 2001; Stuart, 2000) that can be accessed through the ties with alters. This notion is related to the resource-based view of the firm that recognizes as an antecedent of performance the firm's endowment of resources and its heterogeneity among firms. Particular attention is dedicated there to material resource availability within the firm boundaries (Wernerfelt, 1984; Dierickx & Cool, 1989; Barney, 1991; Mahoney & Pandian, 1992; Peteraf, 1993). However, no attention has been given to the network in which firms are situated (Barney, 1991). Dyer and Singh (1998) overcame this limit by developing a relational view of resources, in which the unit of analysis is the exchange relationship between firms in dyadic or network form. This relational view is introduced to explain the competitive advantage of individual firms due to resources that span the boundaries of individual firms or are embedded in inter-firm routines and processes (Dyer & Singh, 1998). Similarly, Gulati (2007) introduced in this regard the construct of *network resources*, "resources that accrue to a firm from its ties with key external constituents including partners, suppliers, and customers, and thus exist outside a firm's boundaries". Firms, through networks, can leverage valuable resources that have arisen outside the firm. In turn, network resources shape firms' behavior and outcomes (e.g. Gulati, 1999; Jensen, 2003; Zaheer & Bell, 2005; Lavie, 2006). An example of the application of network methods in existing organizational theories is the research in the resource dependence tradition (Pfeffer & Salancik, 1978), which fits this context well. It is usually carried out using ego-network data. Resource dependence notions of interconnectedness and constraint are in common with the network approach.

As for the information, we know that information benefits manifest themselves in three forms: *access, timing and referral* (Burt, 1992). *Access* means a broader information screen. It refers to receiving a valuable piece of information and knowing who can use it. If a node has access it has a higher chance to identify opportunities. *Timing* means to get relevant information earlier than the average node receives it. Obviously this implies a greater opportunity to act or to pass the information to others. *Referral* means the legitimization the node receives inside the network through the information about it provided from its alters to their other contacts (Burt, 1992). As a consequence, the node is more likely to be a candidate for inclusion in new opportunities.

One structural property that assures information benefits and resource availability is undoubtedly centrality. There are different forms of centrality: a node can be central as for degree, betweenness, or closeness (Brass & Burkhardt, 1992). This means respectively to be connected to many other alters, to be in the middle of paths that connects others, or to have immediate access to others who are connected.

(c) Integration of the two perspectives

When the aim of the analysis shifts to the understanding and identification of the network configuration that is most suitable for knowledge gathering, it is natural to overlap the two perspectives explained above, the structuralist and the connectionist approach. The ability to catch information and resources is a function of the kinds of ties and of the range of the available knowledge, meaning the diversity of knowledge that can be accessed. In this field, the heterophily theory has arisen, including the concepts of the strength of weak ties and structural holes, along with arguments contrasting it.

First, the starting assumption is that different kinds of ties have different capacities for extracting resources (Borgatti & Cross, 2003). Granovetter's results (1974) suggest differing levels of efficacy between strong and weak ties. He classifies strength as a function of the following four criteria: duration, emotional intensity, intimacy, exchange of services. We can add multiplexity as the fifth criterion to understand the plurality of link interactions (Degenne & Forsé, 1999), so that the strength consists in the presence of different types of relationships simultaneously.

Empirical works have assessed the benefits of embedded ties, considered as closer and more exclusive ties, long-lasting, repeated, and socially dense relationships. Repetitive market relations and the combination of social and business relationships generate embedded dynamics of exchange different from those typical of traditional arm's length ties (Di Maggio & Louch, 1998; Uzzi, 1996, 1999; Uzzi & Gillespie, 2002). Strong ties allow steady flows of information, trust, reciprocity and long-term perspective.

While some scholars have supported the strength of strong ties argument (Krackhardt, 1992; Nelson, 1989), a more pervasive and counterintuitive idea was the one of Granovetter (1973), who assumed the strength of weak ties. Weak ties allow relations *within* groups and are likely to be *bridges* (Friedkin, 1980), while no strong ties are bridges. The bridge is an edge connecting two actors, being the only link that spans among two different parts of a network, and allows diversity of contacts and non-redundancy of information.

The distinctive and complementary roles of weak and strong ties lead to the idea that integrating strong and weak ties within the same network would guarantee superior firm-level outcomes due to the coexisting opportunities for *exploitation* and *exploration* (Capaldo, 2007). Recent social network research has suggested that firms will tend to survive longer if they have a network of both close and arm's length partners (Uzzi, 1996). This conclusion is partially related to complexity theory: from a complexity perspective, under-connected fields tend to be too disorganized to adapt to environmental changes, partially connected (or loosely coupled) actors constitute adaptive fields, while over-connected (tightly coupled actors) constitute gridlocked fields (Eisehnardt & Bhatia, 2002).

This trade-off between strong and weak ties was further advanced and led to an equivalent dichotomy between dense and sparse structure or closure and brokerage. This is mainly represented by two competing and well-known schools of thought. One school focuses on the benefits of brokerage, and disconnected network structure (Burt, 1992), the other on the advantages of closure, and a dense and cohesive network structure (Coleman, 1988; Walker, Kogut & Shan, 1997).

Burt argues that the spanning of structural holes provides the actual mechanism relating weak ties to positive outcomes in Granovetter's (1973) strength of weak ties theory. He equates social capital with the lack of ties among an actor's alters, a condition he names structural holes. In Burt's terminology, a structural hole exists between the brokered actors, two nodes in an ego's network, if the nodes share a tie with the ego but are not connected to each other. The value of Burt's view relies also on the fact that it is drawn from both the structuralist and connectionist perspectives explained above. The broker advantage consists in both information and control benefits. The arguments for the control benefits of structural holes are structuralist and do not explicitly address flows: the broker can play the role of a tertius gaudens, playing off the unconnected others and it can have higher opportunities in general, monitoring the context. The argument for information benefits is connectionist and states that the broker can maximize the amount of non-redundant information he receives. There is no reason to have ties with two connected actors that already share information that tends therefore to be in common and overlap. Network positions associated with the highest economic return lie *between* not *within* dense regions of relationships, in those sparse regions that are *structural holes,* defined by boundaries between groups. Brokers can exploit that information to their advantage (Burt, 1992), and are in an advantageous position for identifying arbitrage opportunities (Burt, 1997, 2004; Hargadon & Sutton, 1997; Zaheer & Bell, 2005; Shipilov, 2006). In this thesis I underline the intrinsic role of the supplier as a strategic broker spanning holes between other actors (two competing buyers or a buyer and a supplier).

On the other side, Coleman's (1990) view of social capital calls for a dense ego-network. In this kind of structure the ego's alters are able to coordinate with each other to help the ego. Coleman's view is similar to that of Putnam (2000) who defines a group's social capital in terms of broad cross-cutting interconnections among all group members.

In conclusion, brokerage allows efficient access to resources, new opportunities, diverse experiences, new understandings regarding emergent threats and chances, and flexibility. Closure provides numerous communication channels, discourages misbehavior, reduces the risks with trust, and thus facilitates collaboration. The combination of the two would be the optimal solution. Uzzi (1996) notes that firms in networks benefit from inter-firm resource pooling and cooperation: the first is achieved through open networks, the second through closed networks. The available empirical evidence supports brokerage over network closure as the source of social capital, though closure can be a significant factor in realizing the value buried in a structural hole (Burt, 2000).

In line with the connectionist perspective, some studies have examined the causes of network formation. Examples of works on a network's antecedents are those explaining a network in terms of actor personalities and latent propensities (e.g., Mehra et al., 2001). Others explore how and why organizations form ties and select partners (whether interlocking directorates or alliances or supply chains), or study the effects of proximity and homophily (McPherson et al., 2001).

(d) Networks and innovation

The effect of networks on innovation can be firstly traced back to resources availability and knowledge sharing, explained above, which are difficult to obtain by other means (DeBresson & Amesse, 1991; Freeman, 1991; Kale et al., 2000; Kogut, 2000; Oliver, 2001; Rosenkopf & Nerkar, 2001). Secondly it is dependent on the interactive learning processes occurring among the network nodes (Inkpen & Tsang, 2005; Powell et al., 1996). Most broadly, such resources encompass resources that a firm's partners may possess and are available to a focal firm thanks to the connection in itself with those firms.

In fact, social network research has contributed to the knowledge-based view of the firm: the network approach helps to explain how organizational knowledge is accumulated and applied, emphasizing that the accumulation and application of knowledge builds organizational capabilities (Grant, 1996). Relationships in networks govern the diffusion of innovative ideas and explain the variability of access to information across competing firms. Innovations are likely to be located in the "interstices between firms, universities, research laboratories, suppliers and customers" (Powell et al., 1996), where complementarity-seeking aims can be achieved. Networks allow the integration of agents characterized by different skills, competencies, and assets that can generate new ideas (Pisano, 1991; Barley et al., 1992; Arora & Gambardella, 1994; Powell et al., 1996; Walker et al., 1997; Orsenigo et al., 2001; Semlinger, 1991; Imai & Baba, 1989). The importance of diverse partners for innovation is proven by some empirical works: Perez and Sanchez's (2002) study on technology networks in the Spanish automotive industry and Romijn and Albu's (2002) work on small high technology firms in the UK. This view is in line with the Schumpeterian (1942) interpretation of innovation as "creative recombination" of existing resources from different fields, of various components and technical solutions.

The relationships also contribute to the creation of the capabilities that can generate economic rents and augment the value of firms (Kogut, 2000). There is evidence that complex knowledge emerges in fact not from work simplification but from the social interactions of individuals within and across organizations (Brown & Duguid, 2000). The importance for knowledge creation of coordinated routines of "synergistic partnering" between informally-connected organizations is a commonly acknowledged result (Powell et al., 1996). Dyer and Nobeoka (2000) have examined in detail the knowledge-sharing routines developed by Toyota to promote superior learning in its supplier network. Arora and Gambardella (1990), although analyzing only the biotechnology industry, have underlined well that is difficult to identify a single innovator in a context of increasing complexity and multi-disciplinarity; since the stock of knowledge itself is located in a complex system of interactions and cooperation among different organizations, they have highlighted the importance of a network made of various types of organizations as the locus of innovation. As the product becomes increasingly modular and knowledge is distributed among organizations (Baldwin & Clark, 2000), collaboration becomes a necessity.

While the benefits usually highlighted are based in the dyadic relationships that put together constitute the network, inter-firm network structures themselves affect learning and innovation (Kogut, 2000; Oliver, 2001; Powell et al., 1996). For example, Powell et al. (1996) suggest that collaborations among biotechnology firms form learning cycles, as follows: since information is dispersed among organizations and is the source of competitive advantage, in this industry, R&D collaborations provide firms with experience in managing ties and access to more diverse sources of information which in turn increase firms' centrality and their subsequent ties. Also, the innovative potential is claimed to be strongly dependent on the overall network structure (e.g., Ahuja, 2000; Zaheer & Bell, 2005).

A systematic review of research (Pittaway, 2004) found that the innovation benefits of networking identified by the literature include: risk sharing; obtaining access to new markets and technologies (Grandori & Soda, 1995); speeding products to market (Almeida & Kogut, 1999); pooling complementary skills (Eisenhardt & Schoonhoven, 1996); safeguarding property rights when complete contracts are not possible (Liebeskind et al., 1996); acting as a key vehicle for obtaining access to external knowledge (Cooke, 1996). Teece (1996) notes that innovation requires a search for both technological and market opportunities. Von Hippel (1988) argues that industries with free flowing information trading have lower search costs and finds that innovation comes more easily. Gulati (1995) and Oliver (1990) highlight that collaboration reduces the exposure of the single firm to the market and the technological uncertainty associated with novel products, avoiding the investments needed otherwise to develop internal capabilities necessary for success.

Other scholars underlined the aim of learning new skills or acquiring tacit knowledge (Hamel, Doz & Prahalad, 1989; Gulati, Khanna & Nohria, 1994; Khanna, Gulati & Nohria, 1998). The flow of tacit knowledge can be greatly favored by the fact that much R&D collaboration is not calculative. In a survey of Swedish companies, Hakansson (1990) found that about half of the development resources went into collaborative efforts, but he characterizes the collaborations as "organic" - informal, initiated out of existing ties and non-predetermined.

According to Chang (2003), inter-organizational cooperation can be viewed as (1) innovation networks, (2) social networks, or (3) value chain networks. Many contributions in the innovation literature suggest that a firm's network of relationships is aimed at achieving higher R&D (Shan, Walker & Kogut, 1994; Podolny, 2001; Ahuja, 2000). Also, researchers claim that the firm needs to establish an effective innovation network of customers, suppliers, competitors, universities and research institutions, etc. (Hakansson, 1987, 1989).

Studies using a social network approach to innovation and product development (e.g. Tushman & Scanlan, 1981) have determined that the position of individuals in the network can favor information dissemination, which in turn favors innovation. However, despite the growing awareness that networks matter, the effects of specific elements of network structure on innovation remain ambiguous (Ahuja, 2000). As explained in the previous paragraph, there is a trade-off between sparse and closed network structures. The first structure is suited for idea generation, the second one for idea implementation (action), as two coexisting elements of innovation.

Brokerage allows the detection and the development of new ideas synthesized across disconnected non-redundant pools of information while closure provides multiple communication channels, and discourages misbehavior, facilitating collaborative efforts. This dichotomy has been addressed by Ahuja (2000), who showed that a contingency approach is needed to evaluate the effects of structural holes on innovation. He proposes two competing hypotheses showing in the results that the negative effect is verified, in contrast with the work of Hargadon and Sutton (1997). The context of the two studies is very different, revealing that in the presence of collaboration between competitors, the development of norms of cooperation, and the improvement of trust and cohesion are particularly important also to reduce opportunism, while in other cases the diversity of knowledge for novel ideas can be more important. This is the case of the second study, in which the focal firm is a product-development consulting firm that bridges structural holes between clients in different industries.

In my work, the supplier (directly linked to the focal motor vehicle company) has the role of a broker and the network acts as a channel in which partners bring the knowledge and experience from their interactions with their other partners to their interaction with the focal firm (Gulati & Gargiulo, 1999). In my context, the supplier that spans holes has the idea generation advantage: it is likely to get knowledge and spur innovation. Implementation often needs the intervention of the buyer so that the supplier, integrating its discovered application in a product, can bring innovation to the market. Intuitively cooperative networks seem particularly important. External linkages are both a means of gaining access to new knowledge and a test of the quality of internal expertise. Inter-firm links provide an opportunity to observe novelty through the approaches of partners, and can stimulate reconsideration of current practices.

The main issue here is that all the works in the literature have illuminated the passive role of social networks in transmitting the information crucial to innovation, but neglected the active role that individuals can play to advocate for innovation. Given that the dependent variable is the buyer's innovation, we must consider the active role of the supplier and of his partners in knowledge sharing. The thesis will investigate this point, focusing on mechanisms enforcing relationships and competition/cooperation issues. The gap that is addressed is to remember that innovation is made of exploration and exploitation and that the second part is not automatically derived from the network structure. The exploitation is given at least by the shift from generating an idea to having a patent granted. There are not so many studies that focus directly on measuring the innovation output of the nodes in terms of exploitation as dependent variable. A study by Debackere, Clarysse and Rappa (1994) analyzes the impact of centrality on research publications authored by the employees of the firms, but the value of this measure is quite doubtful.

Scholars have also under-examined some elements of the network structure. Most research about the relationship between network structure and innovation has prevalently focused on the diffusion of innovations and has not used an analytic approach (Ahuja, 2000). One of the exceptions is the study by Shan, Walker and Kogut (1994) on biotechnology start-ups. They found a positive relationship between innovation output and one element of a firm's network structure: the number of collaborative relationships it formed. They developed a quite sophisticated measure of a firm's network position, but they did not consider other elements of a firm's ego network, apart from the number of direct ties, that might influence innovation output.

Network structure involves two different mechanisms that spur innovation in direct and indirect ties (Ahuja, 2000). Specifically, the number of direct ties a firm maintains can positively affect its innovative output by providing benefits of knowledge sharing, complementarity and scale, with a resultant amount of resources which is proportionally higher than that of a single firm. Indirect ties, which are less costly to maintain, are likely to foster the diffusion of knowledge through knowledge spillovers and information exchange and therefore to enhance the innovation output, although their impact decreases when the presence of direct ties increases (Ahuja, 2000).

Also, the study of the effects of indirect ties should be deepened in the literature. According to Burt (1992), the linkage of a partner with many other partners is beneficial. Resources developed in a direct relationship have implications for the resources available to actors involved in indirect relationships. A contingent approach is needed to analyze more deeply the benefits of indirect ties.

A conclusive remark is that certain types of inter-organizational linkages can be more appropriate to establish technological transactions and to develop innovation (DeBresson & Amesse, 1991). This refers to the trade-off between the effects of strong and weak ties on innovation, similar to the one between closed and sparse structure. There are few studies examining the effect that different network architectures exert on the innovative capability of the network's leading actor (Capaldo, 2007). Some studies have focused on the strength of ties and its impact on innovation (e.g. McEvily & Zaheer, 1999), without finding a unique conclusion. Some of them have claimed the strength of strong ties (Krackhardt, 1992; Nelson, 1989) because of the operational support and joint problem-solving arrangements that they assure (Larson, 1992; Uzzi, 1997). They favor a steady flow of knowledge (Dyer & Nobeoka, 2000; Kale, Singh & Perlmutter, 2000). Others have supported the positive effect of weak ties on innovation because of non-redundant contacts, higher range and the knowledge diversity available (Burt, 1992; Rowley et al., 2000). Also the notion of "overembeddedness" (Uzzi, 1997) suggests that strategic networks composed mostly of strong ties may threaten innovation, rather than enhancing it.

2.2.2 Conclusions

The review, with its focus on two distinct research perspectives that have arisen in the network field, drives to the following conclusions. First, I argue that the adoption of a *contingent approach* is most suitable for the network field. Second, from the theory I identify the contingencies not investigated yet. Third, I underline that social networks analysis can be enriched by analyzing more complex structures. Fourth, I maintain that the line of investigation that reverses the usual logic of social capital, introducing also negative effects, is under-explored. This is related to the aspects of competition also. Finally, works relating networks and innovation have devoted less attention to innovation exploitation. I explain the above-mentioned points in this paragraph.

Network scholars have defined the benefit of the single node in the network both in terms of *structural capital*, emphasizing power and control, and in terms of *social capital*, centered on resources, information and knowledge. The interplay between the two is inevitable while trying to understand the effect of the structural network configuration on knowledge accumulation and innovation. However, as an intrinsic issue, given that the *structure* is just a proxy of the *content* of the ties, we can only presume and infer several different mechanisms that can be in place in a given configuration. When both positive and negative aspects are in place in a configuration, it is unlikely that we can figure out which one of them will prevail. The only available option is to think about the conditions in favor of the occurrence of a given mechanism. This explains why in the network literature several trade-offs and debates are still in place: the strength of strong vs. weak ties and the benefits of closed vs sparse network structures. The main message is that, even stating the unquestionable general positive value and effect of networks, as the highest form of collaboration, a closer look at the different conditions is needed to infer a definite causal relationship between some network/nodal characteristics and properties and the node's performance or innovation output. General statements are risky and we should characterize the network well (e.g. what are the nodes involved in the network, what types of ties are in place) in order to prevent the external validity of the work from being very low. A *contingent approach* is needed and in this field there are some aspects not yet covered by the existing literature.

In particular, the focus of the inter-organizational network literature has been on horizontal ties; vertical ties are rarely considered in the pure network literature. There is no attention to the characterization of the network, in terms of composition, roles played by the different nodes or by the context, in the studies evaluating the effects on innovation. A contingent approach to evaluate the effects of indirect ties is never assumed. A contingent approach to assess the effects of structural holes has already been adopted. Little is known instead about whether, why, and how different network architectures that differ in the strength of their ties exert a different impact on the innovative capability of the lead firm in a network (Capaldo, 2007). Relational and structural embeddedness could be joined together. A basic question that can be further investigated concerns how the focal organization should optimize its portfolio of ties with resource partners. Social network research discusses the liability of unconnectedness for firms in the biotechnology industry (Powell et al., 1996). But going beyond whether the focal firm has connection or not is the question of whether the firm's connections are with closely-linked partners or whether they consist of arm's length market relationships.

Analyzing simultaneously multiple types of edges and nodes can respond to the emerging need in social network analysis to enrich the simple network models with more complex modeling constructs in order to carry out more accurate analyses of the real world. Firms may be connected through a multitude of connections, each of which could be a social network, and researchers have rarely focused on more than one network at a time. In recent years, researchers have begun to explore the complex interplay that may occur among disparate networks in shaping each other and in simultaneously shaping firm behavior and outcomes (Gulati & Gargiulo, 1999) but the field should be further developed.

The extent to which a given network will effectively exhibit a collective resource-creating power is not given a priori. Concerning this, one under-explored line of investigation is that which reverses the usual logic of social capital and examines the negative consequences of social capital, the so-called "dark side", in which social ties imprison actors in maladaptive situations or facilitate undesirable behavior (Gargiulo & Benassi, 1999; Portes & Landolt, 1996; Putnam, 2000; Volker & Flap, 2001). Furthermore, the collective resource-creating power depends on the corporate strategies of the organizations in the network: the dynamics of collaboration and competition in the network are under-examined in relation to the innovation output. Even if collaboration replaces the competitive (win/lose) paradigm which is prevalent in many businesses today, with win/win benefits based on pooling competencies: knowledge, know-how and skills; competition is still a part of the picture. For instance, the diverse knowledge available in the presence of structural holes is often advocated, but it is not just the case that the broker can span the holes between nodes with diverse knowledge bases; it can span the holes also between competitors or not, and this will all have the same effect on innovation exploitation.

In fact, the distinction between exploration and exploitation as coexisting components of innovation is not stressed enough. The focus tends to be on innovation generation, meaning the creation of new ideas, synergistic merging of different skills and competences, or on implementation, in the form of higher/lower involvement in the operational execution. However, in order to prove an effect on innovation output, the innovation should be ready to be marketed if it is to be considered exploited. In fact we can make the following specifications: (i) knowledge can be defined as the inherent intellectual assets that can be effectively exploited through innovation; (ii) innovation encompasses the full spectrum from creative idea generation through full profitable commercialization. Successful innovation depends on converting knowledge stocks and flows into marketable goods and services (Amidon, 2003).

2.3 Supplier-buyer ties and supplier involvement in new product development

2.3.1 Review

(a) Supplier-buyer ties

The most acknowledged contribution on the role of suppliers in the literature is the framework for the structural analysis of industries (Porter, 1980). The bargaining power of suppliers is one of the five structural features shaping the competition in industry. A supplier firm produces items that a buyer firm employs in its value-added chain. The linkages between the supplier's value chain and the buyer's value chain provide opportunities for the buyer firm to enhance its competitive advantage (Porter, 1985). The buyer firm can manage the buyer-supplier relationship in order to gain advantage over its competitors in a variety of ways.

In particular, Shapiro (1985) discusses buyer-supplier relationships and "purchasing as conduit for innovation". Shapiro states that purchasing as a source of innovation is driven by "the desire to take advantage of the best design concepts and technical expertise available". This involves an external focus on seeking out suppliers with design and engineering skills to design a better product than the buyer could. Therefore, buyer firms need to understand the principles that govern the innovative activities of suppliers and institutionalize this understanding in the management of their purchasing activities.

The kind of relationship between buyer and supplier is also fundamental: interaction may be required to develop mutually acceptable specifications (Monteverde & Teece, 1982). The supplier needs to understand the buyer’s characteristics and aims; the buyer will require information in order to design the final product to incorporate the component. Therefore, procuring an innovative component or product necessitates interaction between buyer and supplier. Many companies see the importance of building partnerships in this critical vertical dimension of the value chain as crucial to their success (e.g. Kumar, Scheer &, Steenkamp, 1995; Zaheer & Venkatraman, 1995; Dyer, 2000; Gulati, Lawrence & Puranam, 2005). They recognize that suppliers are an integral part of the value they offer, especially because complete solutions, which require more pieces from suppliers, now constitute a greater portion of their offerings. They can achieve economies of scale and deep specialization. A practice through which firms may accumulate network resources is the maintenance of ties with key suppliers.

Ellram and Cooper (1990) discuss three types of purchasing relationships: arm’s length, supportive and coalitional. The arm’s length is the basic tie, where products and services are purchased as isolated transactions, in the supportive one the supplier is chosen for tangible reasons and usually there are medium-term contracts; in the coalitional, the supplier is chosen also for intangible reasons like strategic fit with the firm and the tie is characterized by sharing of risk and rewards, with a long-term to indefinite horizon. Bevan (1989) uses the term ‘co-makership’ as “buyers and suppliers working together to a common goal”. Bertrand (1986) defines strategic partnerships as “treating the vendors as allies, sharing strategic information freely and drawing on supplier expertise in developing new products”. Landeros and Monczka (1989) discuss five attributes that exist in cooperative buyer-seller relationships: a supplier pool consisting of a few suppliers, an alliance incorporating a credible commitment between the buyer and selling firms, joint problem-solving activities, exchange of information between the firms, and joint adjustment to marketplace conditions.

Firms may even operate simultaneously at multiple levels of collaboration with a given supplier, accessing different commodities or services within different operational contexts (Dyer, 2000; Gulati, Lawrence & Puranam, 2006). Thus, a firm’s network resources can include its multilevel connections with an individual supplier as well as those across groups of suppliers. Some of these connections are deeper than others, but together they provide firms with an array of choices and opportunities that may not be available to other firms.

(b) Supplier involvement in new product development

Scholars studying buyer-supplier relationships have primarily investigated four types of value derived from buyer-supplier relationships: operational performance improvements, integration-based improvements, supplier capability-based improvements and financial performance outcomes, as pointed out in a review by Terpend et al. (2008). Dealing with the effects of supplier-buyer relationships on innovation, in this thesis I am focusing on integration-based improvements, and supplier capability-based improvements. The former refer to improved cooperation and reduction of risk and opportunism. The latter refer to demands by buying firms on their suppliers regarding capability-based goals such as achieving new product development (Terpend et al., 2008). Both elements are taken into consideration in the literature on supplier involvement in new product development, which I will try to extend.

The value of including suppliers in new product development has been widely documented in the supply chain literature (Hyun, 1994; Lincoln et al., 1998). A review (Pittaway, 2004) shows that the effective integration of suppliers in new product development processes can have a positive impact both on the project and on the buyer. First, as regards the projects, it reduces costs and improves quality, technology, speed and responsiveness (Ragatz et al., 1997; Ritter & Gemünden, 2003) and it provides clearer focus on the projects (Ragatz et al., 1997). It assists with improvements in the overall design effort (Conway, 1995), it enables firms to bring in wider expertise during the development process (Romijn & Albu, 2002), and improves communication between the partners (Reed & Walsh, 2002). Second, as regards the buyer, it helps manufacturers to identify improvements that are necessary for them to remain competitive (Lincoln et al., 1998; Perez and Sanchez, 2002) and creates easier access to supplier knowledge and expertise in the longer term (Lorenzoni & Lipparini, 1999). Therefore studies show that supplier involvement in NPD projects has the potential to improve NPD effectiveness and efficiency; consequently, an innovation advantage can be inferred.

Fewer works have focused directly on innovation output. We review some of them. Knudsen (2007) and Wynstra and Pierick (2000) directly assert that supplier involvement has a positive effect on innovative performance; De Propris (2000) finds that firms that co-operate with buyers and suppliers tend to increase their ability to innovate. The integration of suppliers in the innovation process has been highlighted as one of the factors leading to frame-breaking innovation in the study of Kaufmann and Tödtling (2001). They proved that the most important partners for the firm are from the business sector - customers (33.5% of firms) and suppliers (21.9% of firms). Incremental innovations rely more frequently on the firm's customers as innovation partners (Biemans, 1991), whereas firms having products new to the market are more likely to collaborate with suppliers and consultants (Baiman & Rajan, 2002; Ragatz et al., 1997). Lamming (2002) demonstrates that vertical integration may discourage innovation, especially on the part of suppliers. Lean supply is not just about the elimination of waste in order to lower costs and improve efficiency; it also has implications for innovation, releasing the innovative capability of suppliers. Lamming (2002) also pointed out the importance of the move away from purely contractual relations in favor of new partnership supplier relations based on collaboration. On the same theme some authors have introduced a distinction between different models of supplier involvement: Bonaccorsi and Lipparini (1994) (traditional, Japanese, advanced/partnership model), Kamath and Liker (1994) (partner, mature, child, and contractual typology).

However, Johnsen (2009) illustrates how, despite the apparent benefits of supplier involvement in NPD, research remains fragmented and in some cases the empirical findings show conflicting results. Originally, during the eighties, the literature focused on the point that involving suppliers in NPD was a key factor in explaining the "Japanese companies' performance advantage" over Western auto companies in the automotive industry setting (Imai et al., 1985; Takeuchi & Nonaka, 1986; Clark, 1989; Clark & Fujimoto, 1991). Afterwards, studies filtered into a range of other sectors. Most studies highlighted supplier involvement benefits in the presence of technological certainty (Takeishsi, 2001; Walter, 2003; Petersen et al., 2005; Van Echtelt et al., 2007). In the presence of technology unpredictable projects (e.g. radical innovation), while some found advantages (Wasti & Liker, 1997; Song & Di Benedetto, 2008), others found no significative or negative effect (Eisenhardt & Tabrizi, 1995; Swink, 1999; Primo & Amundson, 2002).

A central starting point for the analysis is that to explain these variations in the innovation outcomes two main aspects have traditionally been considered. They are explored by two main streams of research and they are: a) supplier selection, b) supplier relationship development and adaptation. I briefly analyze both.

First, with regard to supplier selection, selecting the “right” supplier for integration has been proven to be positively associated with improved new product development effectiveness. However, to the best of my knowledge, up to now, only firm-level characteristics of the supplier have been considered. Previous works (Hartley et al., 1997; Petersen et al., 2005) have identified culture and innovative capability as the main firm-level suppliers’ characteristics for innovation technical capabilities. Supplier involvement in agreeing technical metrics and targets is equally important. Johnsen et al. (2006) argue that the right suppliers may contribute specialized capabilities that are critical to being able to produce a new product.

Second, with regard to supplier relationship development and adaptation, there is a dyadic research tradition in supply chain management that has informed us of the fundamental buyer–supplier relationship characteristics such as cooperation, trust, and commitment. Several authors have identified the critical role of some relationship-specific factors: training (Ragats et al., 1997), trust and commitment (LaBahn & Krapfel, 2000), risk and reward sharing (Ragatz et al., 1997), agreed performance measurements (Petersen et al., 2005), and supplier capability confidence. Walter (2003) studied people-integration, highlighting the importance of what he termed “relationship promoters” as a way to increase the trust and commitment of suppliers. He investigated supplier involvement, from the perspective of suppliers, to identify how they perceive their involvement in customers’ NPD projects. As Choi and Wu (2008) pointed out, the majority of existing research on supplier involvement remains dyadic in focus. The dyad is the smallest unit made up of two nodes (a buyer and a supplier) and the link that connects them (a buyer– supplier relationship). However, in order to capture the essence of a network, also the way in which a link affects another link must be analyzed. Therefore, they propose the triad (buyer-supplier-supplier) as the unit of analysis, this being the smallest unit of network arrangement where this occurs. According to them, as the next logical step after having studied dyadic buyer–supplier relationships for several decades, a triadic relationship perspective becomes imperative to further understand the buyer– supplier dynamics in supply networks. But, as Dubois (2009) underlines, while it is easy to agree with Choi and Wu (2009) concerning the limitation of dyadic analyses in relation to understanding network processes, substituting triads for dyads may not be a viable alternative. In fact, any chosen triad is arbitrary in relation to others in the context of the wider network of which it is a part. The network perspective introduces several interesting avenues for research, as this remains a gap in the existing works.

2.3.2 Conclusions

The review suggests the following conclusions. The buyer, in order to get a competitive advantage, can exploit the contact points between its value chain and supplier's value chain. One of its strategic choices concerns the potential establishment of relationships with different level of mutual involvement and collaboration. Literature has acknowledged also the existence of multiple kinds of ties simultaneously with the same supplier, but this topic has received little attention in the previous studies.

In the supplier-buyer relationships literature, a causal relationship has been established between innovation output and two main aspects: *supplier selection* and *supplier relationship development and adaptation*, the first one underlining the firm's technical characteristics, the second one focused on the dyadic dimension. Some scholars have advocated the opportunity to introduce the concept of embeddedness in this field also: innovation can be a result of the supplier's overall network characteristics. I try to study both aspects analyzed in the past researches, supplier selection and supplier relationship development and adaptation, at the network level. In fact I shift from suppliers' firm-level characteristics to network-level characteristics and I take into consideration the quality and type of the relations in the network. I examine also the number of different types of relationships (multiplexity) in the network. This way I can figure out how the supplier's extended connections and the characteristics of these connections (incentives, enforcing mechanisms, etc.) cause different outcomes for the actors' innovation. Furthermore, focusing on the supplier's set of relationships made it evident that the literature has never emphasized an intrinsic role of the supplier, that of strategic broker among buyers and other suppliers, and gatekeeper. Also, a contingent approach could be applied to evaluate this role depending on the context, which can be cooperative or competitive.

2.4 Transaction costs economics

2.4.1 Review

(a*) TCE*

In the 1980s transaction cost economics (TCE) was the prevalent approach adopted in the study of inter-organizational ties. Even if TCE shifts the focus of the analysis from the firm to the tie, this is always interpreted as a transaction as opposed to a relationship. Furthermore, TCE reverses the traditional logic of embeddedness (used in the social capital theory) by asserting the primacy of economic performance, in particular cost minimization, as a driver of exchange behavior. In fact, cooperative agreements are considered the optimal solution when neither the market (arm's length tie) nor internalization (vertical integration) can minimize the sum of production and transaction costs[2], and the business network is just considered as an alternative form of governance (Kogut, 1988; Hennart, 1988; Jarillo, 1988; Williamson, 1991).

Coase (1937) asserts that a firm is an island of authority allocation in a sea of market relationships. A firm will expand the size and range of operation until the marginal costs of using internal authority relationships are equal to the marginal costs of using the market. Richardson (1972) overcomes Coase's view by assuming that the simple dichotomy between market and hierarchy is misleading, ignoring the importance of the network of non-market relationships between firms that is needed when the degree of complementary coordination is high and complex. Several studies have developed a framework of strategic networks by incorporating TCE and the value chain. For instance, Jarillo (1988) identified the economic efficiency of networks in the reduction of transaction cost and in the possibility for the firm to specialize in those activities of the value chain that are essential to its competitive advantage.

However, since the focus in TCE is on cost reductions rather than the creation of new areas of value, more specific questions about how cooperative arrangements might affect innovation were relegated to a minor role. Furthermore, if the firm engages in them, the advice is to be suspicious of its own partners and of the results of collaborative arrangements. The focus of the

[2] Transaction costs are the direct costs of monitoring and enforcing contingent contracts as well as costs related to ex ante and ex post performance inefficiency. More specifically, ex ante costs of contracting refer to drafting, negotiating, safeguarding the agreement: the ex post costs refer to monitoring, settling disputes, renegotiating, arbitration and litigation (Williamson, 1975, 2000).

theory is on the avoidance of opportunism, the firm is seen as an “avoider of the negative” instead of as a “creator of the positive”, of rare inimitable resources.

In fact, TCE rests on two key behavioral assumptions: opportunism and bounded rationality (Williamson, 1991). To undertake transactions (carried out through contracts) means facing a variety of potential contractual and organizational hazards linked to the attributes of the transaction. Bounded rationality implies that it is impossible to achieve complete contracts. It means that economic agents do not have perfect information or the cognitive capacity to make use of perfect information, so they cannot work out all the possible outcomes and calculate the optimal course of action. Opportunism is defined as “the self-interest with guile” (Williamson, 1991), meaning that deviousness should be expected from trading partners, who can break a contract if it is in their interest to do so, or supply false information if there is no penalty for doing so. Opportunism means that incomplete contracts are expensive.

As already stated, the organizational form should be a function of transaction costs but these costs are difficult to measure, so Williamson made an abstraction, introducing a proxy of them in the form of three measurable dimensions of a transaction: (i) asset specificity, (ii) uncertainty, (iii) frequency and duration. Firstly, assets are specific if they are lasting and cannot easily be redeployed to other uses. An investment in them makes the party vulnerable to opportunism from the other partner who will try to renegotiate the terms. Complex contractual safeguards are usually required before making such investments. Secondly, uncertainty, or the impossibility of forecasting all the circumstances, can arise mainly in three forms: (1) primary, coming from the occurrence of a different state of the world with respect to what was originally expected; (2) secondary, deriving from the imperfect sharing of information between the parties (asymmetric information); (3) tertiary, deriving from the uncertainty that the partner will behave as supposed. This is something not deeply analyzed in the literature. Lastly, the frequency and duration of the transaction foster the development of idiosyncratic rules and procedures to solve problems and, through the “shadow of the future”, deter a single act of opportunism (to avoid a reaction of negative attitude in the future). In a social perspective also, not considered here, the “shadow of others” could affect the party’s behavior.

Therefore, in general, alliances are formed as a defense mechanism in the presence of strategic uncertainty (Boccardelli et al. 2009). Hennart (1988) highlighted that an alliance is not successful if it cannot help to reduce behavioral uncertainty and subsequent monitoring mechanisms. Kogut (1988) demonstrated that high levels of uncertainty spur the formation of joint ventures when a firm’s performance is critically affected. Some empirical studies in the automotive industry are provided by Monteverde and Teece (1982) and by Klein, Crawford and Alchian (1978). The first concluded that the most important variables favoring vertical integration were the level of engineering skill required in designing a component and whether the component was specific to the manufacturer. The second examined the relation between GM and a supplier of car bodies, who was unwilling to increase its specific investments without enforcing mechanisms.

The general conclusion is that in order to protect transaction-specific assets from opportunistic appropriation, firms will choose to increase the extent of hierarchical control over the other party in the relationship. Ownership is the principal means proposed by TCE to guarantee control and access to assets. However there are other social devices that may turn out to be more efficient: the hybrid vertical solution is an answer to this need to move from the buy option to the make option. The underlying principle is that the less the competition, the more likely is the exposure to a small amount of bargaining and opportunistic behavior.

(b) *TCE and innovation*

Although Williamson does not apply his analysis to the location of R&D, Teece (1988) and Kay (1988) have examined the economic arguments for subcontracted versus in-house R&D, using the concepts of market and hierarchy without explicitly mentioning transaction costs. They identified the factors that tend to encourage in-house rather than subcontracted R&D. They are tacit knowledge, cumulative learning processes, the presence of non-product-specific research, the difficulty of pricing and the timescales involved.

Teece (1986) maintained that in a context of R&D, each one of the different organizational configurations (namely arm’s length transactions, vertical integration, collaboration) has some specific characteristics influencing the capability to achieve rewards from innovation. First, arm’s length transactions can have high costs, but are useful when technology is codified, discrete (non-systemic) and relatively simple. Second, vertical integration limits transaction costs, but prevents the access of specializations in other firms. Third, collaboration allows these specialist skills to be accessed, can allow complex and tacit knowledge to be transferred and technology to be unbundled.

One criticism of the application of TCE to R&D has been proposed by Leveque et al. (1996). They pointed out that the market versus hierarchy approach, applied to the creation of technology, implies substitutability between external and internal R&D. In this way, it ignores the role played by in-house R&D of not only generating innovation but also increasing the firm's absorptive capacity. Also, they highlighted that strategic alliances are more concerned with creating new knowledge than with using existing knowledge in a situation of uncertainty, an element not considered in the transaction cost approach.

2.4.2 Conclusions

TCE's central idea of the existence of two extremes, market and hierarchy, as governance mechanisms of the economic activity, is a reference point to organize a framework for the analysis of networks and alliances. These are meant to be an intermediate or hybrid organizational form. The theory highlights the need to consider the cost-minimizing, competitive, and profitability aims even in the context of linkages and emphasizes the risky side of collaboration. The main constructs used in the theory are bounded rationality and opportunism. The evaluation of the optimal organizational form is contingent on some dimensions of the transaction: asset specificity, frequency and duration, and uncertainty. Collaborative efficiency and efficacy is assumed to be achieved on the part of the firm when the firm can limit its partner's opportunistic behavior. The advice is to be suspicious of one's own partners and of the results of collaborative arrangements.

The aim is not just to "create the positive" but to "avoid the negative". This is a positive aspect, and at the same time the weakness of the TCE approach. This assumption is antithetical to the approaches which emphasize "social" considerations, and in fact TCE has been accused of offering an under-socialised perspective of the actors (Granovetter, 1985).

Basically, TCE neglects the aspect of the creation of new areas of value in a transaction. It fails to capture aspects of effective learning between firms that enable the development of competences. It ignores interpersonal and inter-firm trust, as well as the evolution of inter-partner relationships.

Being focused only on cost minimization, it ignores the difference in firms' capabilities. When Williamson presented vertical integration as a preferable solution, he paid no attention to production costs, which are also a function of a firm's capabilities. TCE considers many things, such as preferences, capabilities, perceptions and knowledge, to be stable and given exogenously (Nooteboom, 1992).

In order to partially overcome the above-mentioned limits, Nooteboom (1992) introduced a so-called "generalized transaction cost theory", based on a competence perspective. It included also the concept of commitment and trust. It relied on a dynamic efficiency principle: efficiency in innovation, which is characterized by shifts in knowledge, technology and preference.

The above remarks make clear that specific questions about how cooperative arrangements might affect innovation have been under-examined. In the end, TCE is focused on the allocation and not on the creation of resources. This is not satisfying; however, this shows that TCE must be included in any study on innovation that would consider the exploitation of the new idea and not just the generation of it. The threat of opportunistic behavior can impede the achievement of the expected results also in the presence of asset specificity, which is frequent in an innovative project.

Finally, despite the fact that in discussing his embeddedness perspective Granovetter (1985) explicitly contrasted it with transaction cost economics (Williamson, 1975), later theorists have identified further potential in marrying the two perspectives (Blumberg, 2001; Jones, Hesterly & Borgatti, 1997). A network approach to transactions and contracts can potentially illuminate patterns of ties focused not on actors but on interactions in the form of transactions or contracts. An important remark is that when adding a network perspective, transaction costs for a node are a function of the attributes of the other transactions of its partners. The incentive a partner has to behave opportunistically is dependent on the opportunities or constraints in the transactions with its other partners. The likelihood of breaking a contract or violating common rules is a function of the benefits the actor can get in the relationships with the totality of its partners. In general, one of the TCE conclusions is that the less the competition, the more likely is the exposure to a small amount of bargaining and opportunistic behavior.

2.5 Competition, cooperation, innovation

2.5.1 Review

There is an inherent dilemma between firms' competitive aims and cooperative means, which we have analyzed above. Miles and Snow (1986) in their conception of *dynamic networks* maintain that industrial structures are disaggregated, market transactions replace previously internalized activities, and competitiveness relies on the ways in which firms interact with one another. The search for new partners and new technologies reshapes the very basis of cooperation and competition.

For Hamel, Doz and Prahalad (1989), collaboration needs to be viewed in a competitive power perspective. Collaboration is a continuation of competition, and should be seen, as Harrigan (1986) argues, as a transitional stage in firm positioning. The combination of competition and cooperation in a single novel conceptual lens that is “coopetition” is provided in the works of Brandenburger and Nalebuff (1996) and Dagnino and Rocco (2009).

The coopetitive approach highlights the presence of a new kind of strategic interdependence among firms, where processes of both value creation and value sharing take place, creating a partially convergent interest and goal structure, with cooperative and competitive issues (Dagnino & Rocco, 2009). This tries to overcome the limits of the two individual perspectives: the cooperation approach that under-examined the way in which the value jointly created is transformed into actual benefit for the single firm; and the competition approach which assumes that a firm’s interdependence is based only on an individual interest search, neglecting social elements of the interaction. Merging the two approaches means drawing on different streams of research: mainly, strategic management (Porter, 1980; Barney, 1986) and organizational economics, TCE (Williamson, 1975, 1985) for competition; strategic management (Contractor & Lorange, 1988; Hamel et al., 1989; Dyer & Singh, 1998) and social capital theory (Granovetter, 1985) for cooperation.

Competition derives from similarity in positions occupied in the resource space - two organizations compete to the extent that their niche overlap. However the development of similar structural interests intrinsic in the shared dependence on resources, makes organizations more likely to collaborate (Lomi & Pallotti, 2012).

Agreements and alliances are instruments of corporate strategy in the complex interplay of cooperation and competition. This interplay characterizes rivalry among oligopolists (Porter & Fuller, 1986; Hamel et al., 1989). This also quite possibly involves some degree of overt or tacit collusion among partners (Contractor & Lorange, 1988), as well as the building of collective barriers to entry (Chesnais, 1988).

The approaches focusing on economic and competitive relations clearly identify long-term corporate survival and growth as a key motive of inter-firm links. They introduce the question of power between firms, and the ways to maintain dominant positions, considering exclusionary rules and control objectives. Thus links may be formed to pre-empt competitors doing the same (van Tulder & Junne, 1988) or to raise entry barriers. Firms may use links to increase the control over suppliers (Lamming, 1992, 1993). Alternatively, firms may give up autonomy in the generation and diffusion of technology, and develop strategies for sharing control over technology in order to retain that control (Dodgson, 1989). According to these perspectives, the configuration of a firm's value chain, the range of in-house activities, the capability to organize subcontracting and technology-sourcing agreements in order to appropriate for itself a part of the value produced by other allied firms, are key issues of corporate strategy.

Powell et al. (1996) state that cooperation, competition, and power all contribute in different ways to the expansion of networks of production. Collaborative production is now more than the sum of several bilateral relationships. Even if collaboration takes place between two parties, each party is involved in multiple forms of cooperation. The consequences of these multiplex ties are significant. In a collaboration network, firms are often engaged in close but not exclusive relations with other companies. Therefore also the unit of analysis of competition is shifted in some way from the firm to the tie: competition does not occur on a firm-to-firm basis but among different alliances on a project-by-project basis. In the end also networks compete with one another. There are some interesting features of this emerging form of competition: the competitive relationship is altered when two parties compete on one project but collaborate on another; given that the firm is a bundle of complex projects, it should know the capabilities of all its partners in order to evaluate ex ante the likelihood of success (Powell et al., 1996).

Profiting from cooperation implies a process that must be carefully managed. One of the most common outputs the firm intends to achieve through cooperation is learning, knowledge, and innovation. The role of learning as a competitive weapon has been analyzed by several authors, in relation with the concept of the learning organization (De Geus, 1988; Stata, 1989; Senge, 1990), envisioning the role of an organization as part of an expanding enterprise. As already clarified, innovation includes knowledge creation and extends to knowledge conversion and commercialization. The appropriability of the idea generated in the collaborative setting becomes an important question in this analysis. The alliance literature reflects the presence of both benefits and risks associated with inter-firm arrangements. The firm sharing information with partners is potentially putting itself at a disadvantage if the receiving firm can misappropriate the information (Baiman & Rajan, 2002).

As highlighted by MacDonald and Ryall (2004), a fundamental question in business strategy is: “How does competition among economic actors determine the value each appropriates?”. Porter (1980) says that the essence of strategy formulation is coping with competition. I mention the answer of some theoretical perspectives. From industrial organization we know that the more the situation seems monopoly-like, the better the prospects of appropriation are. From RBV we derive that the greater the ownership of a scarce resource, the higher the appropriation. In the thesis I try to consider the first view by introducing the number of relationships (centrality in the network) and the second view by introducing the strength of relationship (determining the level of idiosyncratic assets). From patent race literature, we conclude that appropriation depends on the control over a useful entity, like a patent, for which there is competition. This is competition for the product market: the race to be the first to bring a new product to market or to produce by means of a new technology.

In the literature, game theory has provided some tools and perspectives to deal with such a case (Morris, 1992; Powell, 1999; Brams, 1994; Axelrod, 1984) and look for a “self-conscious interactive” solution (Ghemawat, 1997). The participants are struggling over a fixed asset and one player’s gain is the other’s loss. Such a situation, known as zero-sum, leads to a degree of aggression, not present where the contested resource is expandable through cooperation. This cooperation is not necessarily overt. In a context like this, the companies will be optimizing their moves so as to bring down the other as much as to enhance their own position, since the objectives amount to the same thing. However, assuming a broader point of view, the single project is part of a larger more cooperative game, since there is a component of one company's action which helps the other. Whether or not the game is repeated changes the course of the actions.

2.5.2 Conclusions

The starting point of the analysis is that collaborative agreements alter the competitiveness of the partners and that competition alters the cooperative dynamics inside a network of ties. The short review shows that the topic of the coexistence and interplay of collaboration and competition in shaping firms' payoff spans different streams of research, and it is central in the "coopetition" approach. The main aim of this perspective is to join the value creation and value sharing processes in firms' interdependences. At the same time, it is difficult to find in the literature definite solutions regarding some questions related to the field (e.g., which of the partners appropriate the value and through which mechanism, what determines the extent and direction of skill transfer within an alliance, what are the implications of inter-partner learning for power and dependence). A contingent and context-specific approach is needed to answer the questions and the use of both social capital theory and transaction costs theory can help in this aim, allowing us also, through an integrative approach, to develop a more powerful and more balanced alternative for studying inter-organizational relationships. The competitive advantage of the firm is dependent on the information flowing in and out the firm and on the nexus of contracts/transactions established by the firm.

The aim of the research is to understand how both learning and competition influence the relationship value (Cheung et al., 2010) for a node of the network. The main characteristics of the context analyzed are the coexistence of competition and collaboration among partners (buyers) indirectly linked through the shared supplier. They compete for the appropriation of knowledge and innovation but at the same time they collaborate, contributing to the generation of novel ideas and to the process of knowledge accumulation and capabilities enhancement on the part of the shared supplier. In the end, the network may convey innovation benefits either as diffuse channels for information spillovers or as proprietary pathways for directed information and resource transfer between partners (Owen-Smith & Powell, 2004). I am going to figure out which are the contingency factors for the two options. The thesis advances research on strategic alliances and tries to solve the ambiguity of cooperative and competitive effects on innovation also in indirect ties. In effect, in the work the focus is on vertical alliances that do not imply direct competition, but engender indirect competition (supplier-mediated competition among buyers or buyer-mediated competition among suppliers. I will focus on the first one.). In this sense, we are moving vertical alliances closer to horizontal alliances. It is interesting to figure out what are the consequences and which network structure is suitable to obtain advantages and not disadvantages from this situation.

I conclude the chapter by underlining that, in view of the incompleteness of both the TCE and the social capital approach, I try to adopt a more balanced alternative for studying inter-organizational relationships, with the integration of the two perspectives. The adoption of the network perspective will enrich supplier-buyer relationships literature, considering the supplier as a strategic broker. As regards innovation, both exploration, that is value creation, and exploitation, that is value sharing, will be considered, as is rarely done in the social network studies. Given these premises, the interplay of cooperation and competition will come into the picture.

CHAPTER III - Hypotheses development

On the basis of the literature reviewed in chapter two, I develop my theoretical model and hypotheses that establish a causal relationship between the characteristics of the supplier's network and the focal buyer's innovation output. I adopt a positional network approach to postulate two main effects regarding the impact of the supplier's network centrality on the buyer's innovation output. Supplier's centrality in a network of suppliers has a positive impact on the buyer's innovative performance, while supplier's centrality in a network of buyers has a negative influence. This suggests that the effect of centrality in a network is dependent on the type of nodes involved in the indirect ties. Then, I adopt a relational network approach to argue that these two main effects are moderated by the strength of the ties in the direct relationships. The strength of the focal buyer-supply tie negatively moderates the first main effect while the relative strength of the focal buyer-supplier tie versus the strength of supplier-other buyers ties positively moderates the second main effect. In this way, I find support for the strength of weak ties in a collaborative context and for the strength of strong ties in a competitive context, where the actors compete for the information and for the exploitation of the innovation.

The chapter has the following structure. The general concepts and mechanisms underlying my theoretical framework are explained first. I develop three central propositions with regard to the effect of indirect ties, network position, and tie strength on firm innovation performance, that are useful for the hypotheses development. I suggest two key mechanisms through which these effects occur: the positive knowledge leakage from the network to the ego and the negative knowledge spillover from the ego to the network. Thereafter, the comprehensive model is outlined to enhance clarity. Finally, the line of reasoning behind each hypothesis and the hypotheses' formulation are presented. I try to integrate network theory, the TCE perspective and the supplier-buyer relationship literature to identify the mechanisms underlying inter-organizational relationships and their effect on innovation output.

3.1 Inter-firm ties, knowledge flow, and innovation

This section analyses the dynamics that determine the impact of inter-firm collaboration on firm innovation performance. The central idea is that collaboration creates both opportunities and limitations for the innovation development. Ties are conduits of knowledge: more ideas for the focal actor but also knowledge spillovers for alters. First, I present some remarks on the process of knowledge flow through the ties. Second, I analyze the innovation production function. Third, I derive three central propositions that are the basis for the hypotheses' development.

3.1.1 Knowledge flow

Knowledge is a fluid and portable good; it is difficult to make it exclusive or to completely control it privately; it is intrinsically a public good. This means that it is basically non-rivalrous and non-excludable. A good is defined as non-rivalrous when it is not diminished by consumption and as non-excludable when attempts to prevent consumption are generally ineffective. As a non-rivalrous good, the knowledge of a fact or idea of an actor does not hamper the knowledge of another actor. In this respect, a quotation of Thomas Jefferson's (1853) reasoning can be very illustrative: "*If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea.... Its peculiar character ... is that no one possesses the less, because every other possesses the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening mine.*" As a non-excludable good, knowledge is embedded, diffused, and available in so many forms that it is almost impossible to hamper the learning opportunities of alters. Knowledge continuously escapes from the entities producing it; thus, it can be used freely by rivals (Foray, 2004). It leaks out in multiple ways, some of which have been the subject of abundant literature. For instance, von Hippel (1988) analyzed the role of informal networks of cooperation and exchange of experience between engineers in different and even rival companies. However, knowledge can also flow just by being embedded in products. The marketing of products that competitors can disassemble is an important source of technological knowledge flow (Foray, 2004) and practices such as reverse engineering are illustrative in this respect.

Therefore, a firm can learn from other firms' innovations whenever the technological contents of their R&D activities are not effectively confined inside their boundaries. Thus, the firm's productivity may depend on the pool of general knowledge that it has access to (Ornaghi, 2006). In fact, the extensive innovation literature has shown that a firm's innovation performance depends not only on internal R&D activities but on a bundling of internal and external knowledge resources (e.g., Cassiman & Veugelers, 2006; Rosenkopf & Nerkar, 2001; Katila, 2002). Many firms open their innovation processes and search for external knowledge from customers, suppliers, and competitors (Chesbrough, 2003). The process is not univocal; therefore, at the same time, knowledge easily flows to competitors, allowing them to free-ride on a firm's R&D investment by imitating novel products, processes, or services (Teece, 1998). Knowledge allows free-riding because it can be consumed at no cost from actors that have not contributed to its creation. Involuntary spillovers are a feature of market competition (Zack, 1999). Competition creates incentives to produce new knowledge as well as to adopt and absorb new knowledge created elsewhere to be aligned with the competitive environment and to avoid being excluded from the market. The level of internal R&D and external knowledge acquisition are not independent of one another, as firms require at least a certain level of internal R&D to identify and absorb external knowledge (Cohen & Levinthal, 1990, 1989). Naturally, the acquisition of knowledge by other firms depends on their learning capacity and the nature of the knowledge analyzed that can be more tacit or codified. This boosts firms in building and developing absorptive capacity (Cohen & Levinthal, 1989).

The arguments presented above explain why inter-firm ties, as conduits of knowledge, can be both beneficial (through the incoming flow) and detrimental (through the outgoing flow) for innovation output. Firms face the challenge of managing incoming and outgoing knowledge flows simultaneously. The flow between an innovation project and the context that can be conceptualized in terms of "leakiness" and "stickiness," both potentially positive and negative (Bengtsson & Ericsson, 2002). Leakiness is the easy flow of knowledge and resources: positive leakiness is the flow into the project, while negative leakiness is the flow out of it. Stickiness is the "mechanisms that hinder the flow" (Bengtsson & Ericsson, 2002). Positive stickiness protects ideas from spreading to competitors; negative stickiness is the hindering of the flow among partners. Inter-firm collaboration has a positive impact on innovation output to the extent that positive leakiness and stickiness are enhanced and negative leakiness and stickiness are reduced.

The point is also that, while knowledge is inherently, to a large extent, a public good (non-rival, hardly excludable, and easily transferred), innovation output tends to be a private good through intellectual property rights application. This dichotomy makes it difficult to determine ex-ante the impact of inter-firm collaboration on firm innovation performance. Innovation can be defined as the application of knowledge to generate technical or organizational changes capable of offering advantages to the firm that accomplishes them (Zawislak et al., 2008). It consists of the research, discovery, experimentation, development, imitation, and adoption of new products, new productive processes, and new forms of organizing resources (Dosi, 1988). Who, then, captures the value that knowledge creates? Most theoretical and empirical models demonstrate that the degree of appropriation of value is typically incomplete (Harabi, 1995; Mansfield, Schwartz, & Wagner, 1981). Not all profits from a resource automatically flow to the company that owns the resource; an organization cannot retain all the benefits resulting from its inventive activity. In fact, the value is always subject to bargaining among a host of players, including competitors, customers, distributors, suppliers, and employees (Zack, 1999). Competition for knowledge and spillovers has a negative effect on the rents that a firm can generate from having a potential temporary monopoly based on the uniqueness of its innovative product. This temporary monopoly is achieved through patents. A patent race can arise; it is defined as a simultaneous race between many teams, all searching for the same innovation and only one achieving it first (Zeira, 2005). This also creates duplication of innovative activity. Integrating knowledge appropriation theory (e.g. Teece, 1986; Katila et al., 2008; Ceccagnoli, 2009) and knowledge search theory (e.g. Katila, 2002; Laursen & Salter, 2006), Grimpe and Sofka (2011) argued that firms' R&D is most effective when thsearch targetsexternal knowledge sources with a low risk of misappropriation, typically economic actors different from competitors.

In conclusion, it is likely that, in the context of inter-firm collaboration, three processes take place. First, a firm can benefit from external knowledge. Second, it can be damaged by the negative spillovers of its own knowledge to alters. Finally, it is in competition with alters for the exploitation of knowledge through innovation patenting. These three elements are the core of the innovation production function: knowledge capital, spillovers, and congestion.

3.1.2 Innovation production function

An effective way to understand better the impact of inter-firm collaboration on innovation performance is to refer to the innovation production function and to analyze its components. As with the microeconomic production function, it is useful to understand the innovative behavior of the firm and identify the determinants of the innovative output. This also makes it easier to maintain a link with the empirical procedures explained later in the dissertation.

As Cohen and Klepper (1991, 1992) highlighted, the principal source generating new economic knowledge is commonly considered to be R&D. Additional inputs in the innovation production function have included measures of human capital, skilled labor, and educational levels. Thus, the model of the innovation production function from the literature on innovation and technological change can be represented as:

I = f (R&D, HK)

where *I* stands for the degree of innovative activity, *R&D* represents R&D inputs, and *HK* represents human capital inputs (Audretsch & Feldman, 2004).

Given this general form, I refer in particular to the innovation production function formulated by Romer (1990). He modeled innovation basically as a function of R&D, spillovers, and congestion. He identifies innovation with a change in the number of blueprints/ideas over time: A. New blueprints/ideas are created from labor inputs L_A building on the existing technology, according to the following formula:

(1) $A = \overline{\delta} L_A$

where $\overline{\delta}$ is the average research productivity, the rate at which an individual researcher discovers new ideas (the number of new ideas generated per researcher). This rate is modeled, in turn, as a function of the existing stock of knowledge/ideas, A; a "spillover" parameter, φ; and a "congestion" parameter, λ.

(2) $\overline{\delta} = \delta A^{\varphi} L_A^{\lambda-1}$

This means that the rate of innovation depends on the existing stock of knowledge available, A, namely the stock of ideas that have already been discovered, and on the number of other researchers according to the following dynamics: (1) positive or negative spillovers from existing knowledge, so a high A might increase or reduce $\overline{\delta}$; (2) congestion effects: if more people do research competitively, efforts might be duplicated or wasted; higher L_A might reduce $\overline{\delta}$ for all the researchers. Taken together, equations (1) and (2) suggest the following innovation production function:

(3) $A = \delta A^{\varphi} L_A^{\lambda}$

According to this expression, the number of new ideas or new knowledge at any given point in time depends on the number of researchers and the existing stock of ideas. The basic version is with $\varphi=0$ and $\lambda=1$; then, $\overline{\delta} = \delta$ is constant, and the research output is proportional to the labor input. $\varphi>0$ captures a positive spillover effect, negative spillover means $\varphi<0$, and congestion means $0< \lambda<1$, in which case research productivity is decreasing in L_A.

I want to underline that, focusing on a firm, the stock of existing knowledge functioning as basis for its knowledge creation, A, is both internal and external to the firm. The internal source refers to the past R&D achievements of the firm, and it is naturally embedded in the organization. Incremental innovation will naturally come up, drawing upon past knowledge, and path dependency also occurs. The external source comes from relationships with other firms through collaboration and knowledge sharing or through knowledge flow in the form of spillovers. The first element implies a voluntary contribution to the creation of a common knowledge pool, while the second element derives from information flowing unintentionally through the ties. Therefore, the function can be expressed as follows:

$$A_{FIRM} = \delta (A_{INT} + A_{EXT})^{\varphi} L_A^{\lambda}$$

where A_{INT} is the existing knowledge inside the organization and A_{EXT} is the knowledge derived from its inter-firm ties. In the case of internal knowledge, the positive spillover effect means "standing on shoulders": current research productivity is positively affected by past research; negative spillover means that the most obvious ideas are discovered first and new ideas become harder to find (Abdih & Joutz, 2006). In the case of external knowledge, the positive spillover is the flow of knowledge into the firm, or positive leakiness, while negative spillover is the flow out of the firm to competitors, or negative leakiness. The external knowledge can be further decomposed in the stock of knowledge owned by the individual firms and in the knowledge created in the interactions in the relationships themselves:

$$A_{FIRM} = \delta (A_{INT} + A_{EXT\text{-}FIRMS} + A_{EXT\text{-}INTERACTION})^{\varphi} L_A^{\lambda}.$$

I start from the innovation function and analyze its components (A, the stock of knowledge available; φ, positive and negative spillovers; and λ, congestion) in the context of the inter-firm collaboration network studied in this dissertation. In the following paragraphs, I briefly explain the mechanisms underlying these components, which, in turn, determine innovation output. I take into account the specificities of my network. This involves suppliers and buyers. I can argue that the importance of networks with other companies is most easily explained in terms of the supply chain. Success in innovation rests crucially on the quality of knowledge flows regarding user needs, the relationship being especially strong among specialist users of complex technologies. Moreover, innovations of all types demand knowledge from suppliers of materials or components incorporated into the final product. As explained before, the network I am analyzing is a multiplex network including supply ties, alliance ties, and supply plus alliance ties. All the relationships involve a knowledge flow, though they may vary in intensity. The ties are also considered to be symmetric (even if they are supply ties with a clear direction where one party supplies the other one) because the focus is on the social interaction of people connecting with people. One could argue that a supply tie implies merely a purchasing process and the incorporation of a component into a final product. However, this is clearly a limiting view as I will explain. The following arguments will also clarify why the relations considered in my hypotheses are suitable for exploring knowledge transfer dynamics.

(a) A^{φ} component in the supply network context

The stock of knowledge available to a focal node in a network results from the combination of two elements: the knowledge owned by the nodes linked to the focal node and the new knowledge created through the relationships with these nodes. I describe the mechanisms that allow this knowledge to flow in an inter-firm supplier-buyer tie. This is useful for the hypotheses development in that the presence of these mechanisms (which is a function of some network characteristics such as the number and the strength of the ties), through knowledge flow, has an impact on the innovation output.

An inter-firm relationship is a mutual orientation of two firms toward each other (Forsgren, Hagg, Hakansson, Johanson, & Mattsson, 1995). This implies that the firms are willing to interact and expect each other to do the same, with trust and attention to the other party's interests. The mutual orientation can also refer to products, production processes, and routines that link the organizations. This implies interaction, a term that per se expresses that business is carried out as a two-way communication between companies; i.e., the companies influence each other (Håkansson, 1982; Johanson, 1989; Turnbull et al, 1996). The interaction between two firms takes place through a lot of episodes involving them, such as, for instance, the placing or delivery of an order, handling of a complaint or a request, visit of a sales manager at the customer's plant, delivery of a spare part, meeting about technical problems, etc.

This interaction comprises two main categories of processes: *exchange processes* and *adaptation processes* (Forsgren, Hagg, Hakansson, Johanson, & Mattsson, 1995). Exchange increases the value of each party (Alderson & Martin, 1965; Bagozzi, 1974) and it is often considered the core of business relationships. In particular, the exchange processes can be substantiated in three types of exchange: *product exchange*, *information exchange*, and *social exchange* (Cook & Emerson, 1978; Håkansson, 1982). *Adaptation processes* imply an effort of the parties to meet mutual needs. Generally, the exchange processes and the adaptation processes are highly correlated. The more intensive the exchange processes are, the stronger the incentives are to make adaptations. I briefly elaborate here on each of these mechanisms.

Product exchange is usually the primary aspect of exchange, and it can be characterized by dimensions such as value, complexity, frequency, regularity, service content, etc. These dimensions vary depending on the significance of the product exchange for the parties, on the resources and efforts the parties want to invest in the relationship, on some characteristics of the firms (e.g., production technology), and on the market (e.g., competition). The complexity of the product and the service content will also define the degree of interaction between the two parties needed to support the product exchange. The product exchange per se creates a supplier-customer relationship between each person and the individual who is responsible for providing that person with each specific good. Even to make a request for parts, to specify the form and the quantity of the goods and services to be provided, or to fix the expected time in which the request should be met, a direct connection between the two organizations is needed (Spear & Bowen, 2006). Referring to the production function, the primary effect is that the knowledge of a firm is embedded in a product and, through the product, enters another organization. This basically corresponds to the $A_{EXT\text{-}FIRMS}$ component.

As a supplementary effect, a product exchange must be supported by an interpersonal connection, generating the other types of exchange that I will present below and creating at least some degree of $A_{EXT\text{-}INTERACTION.}$ The extent of this additional effect is mainly dependent on the specific production model and on whether it implies joint involvement of the parties in product development or not. An example to explain the movement from a pure product exchange to a different type of exchange is provided by Toyota, which divides components into two categories, those that vendors can design by themselves and those that must be developed at Toyota. The first category includes floor consoles, sunroofs, mirrors, locks, and other small components. Suppliers can design those components without constant interaction with Toyota engineers because the parts work relatively independently of the rest of the vehicle. The second category includes parts that interface with the sheet metal and trim of the body. Suppliers must design these components in collaboration with Toyota, with close consultation with the manufacturer's engineers. The "design in" room houses suppliers who work in the same room on the same project. They design components using Toyota CAD systems. Suppliers have to work at Toyota's technical center because the automotive company gives them a lot of proprietary information and they need to work hand in hand with its engineers (Liker & Choi, 2006).

Information exchange is a function of the product exchange: it has the role of facilitating product exchange execution (Hallén et al., 1991). More information exchange is needed if the dimensions (the complexity, frequency, etc.) of the product exchange are increased. This means that the parties will meet more often, that more specialists will have interactions with their counterparts, and that workers on different organizational levels will be involved in the relationship. Information exchange will be also related to the characteristics of the firms (e.g., production technology, cultural distance between the two entities). Information exchange is sometimes not only needed but intentional, and it can be a part of the firm's strategy. In this respect, Chrysler’s philosophy is quite illustrative: "if we inundate vendors with information and keep talking to them intensely they will feel like partners" (Liker & Choi, 2006). Information typically includes operational matters such as product specifications and buyers’ technical requirements. However, it can also refer to a broader set of data such as what kinds of products the supplier intends to introduce and what types of markets it plans to cultivate, strategic directions in terms of technology, globalization, ideas about new products, capital goods, and plant expansion (Liker & Choi, 2006). In the production function, the A_{EXT} and the spillovers are increased.

Social exchange is the richest and strongest form of exchange in a relationship and arises when the parties develop trust in each other. Social exchange relations evolve gradually with higher confidence between two parties that, in the long term, makes possible large mutual commitments. The social exchange process is fundamental for the development of lasting business relationships. Social interaction varies in intensity depending on how many people are involved, how often they meet, and the type of the information they exchange (Cook & Emerson, 1978; 1984; Håkansson & Östberg, 1975). The information that is transferred via social interaction is of a less tangible nature. In the production function, the A_{EXT} and the positive spillovers are increased. The social exchange creates mutual efforts and reduces negative spillovers because one party works in favor of the other and will not behave in a way that can damage the actual and future relationships with the other party.

In all exchanges between two firms, there are elements of all three aspects of exchange. Thus, in product exchange, there is also an element of information exchange and social exchange. This means that the supply ties also convey a form of knowledge from one party to another.

The other side of the interaction is represented by the *adaptation processes* through which the parties adjust to each other. Mutual adaptations are normal in social exchange processes to match each other better and gradually get closer to each other. These processes usually imply specific investments or projects such as the purchase of specific machinery or installation of specific systems. Sometimes adaptations occur through more continuous processes in day-to-day operations. Adaptations can be made in a number of different dimensions: in the production (by modifying products or production processes), in the logistics (by adjusting stock levels or developing joint delivery systems), or in the administration (by modifying planning and scheduling systems). They can also occur in the attitudes, knowledge, and strategies of the parties (development of a common language regarding technical matters, contracting rules, standardization of procedures and processes, expectations about the future developments). More generally, they refer to the commitments made by the parties, ranging from tangible assets (e.g., dedicated equipment and task forces) to intangible resources (e.g., implementation of inter-partner customized routines), to ensure the achievement of collaboration goals (Wang et al., 2001). Adaptations strengthen the bonds between the firms. The firms become increasingly dependent on each other, with higher switching costs, and the exit or change of the partner is no longer a convenient option to solve disagreements between the parties. If a supplier introduces adaptation processes, this means that it makes higher relation-specific investments, which implies higher commitment; in turn, this is an incentive to share information and behavior on behalf of the buyer. This will then spur innovation. The literature underlines the fact that a supplier's investment in relation-specific assets signals its supply assurance and, hence, commitment to a long-term partnership with the buyer (Celly et al., 1999). A buyer would enjoy more control over a supplier and would be more willing to broaden the extent and scope of joint activities with the investing firm. This provides transaction values for inter-firm collaborations (Dyer, 1997). In sum, the literature shows that relation-specific investments have a positive impact on joint actions (Kim, 1999; Zaheer et al., 1998). In particular, the hypothesis tested by Wang et al. (2001), who asserted that "dedicated specificity is positively associated with a supplier's engagement in joint actions with its buyer," confirms the intuition that a supplier's relation-specific investments are a proxy of its orientation toward greater collaboration. In the innovation function, the $A_{EXT-INTERACTION}$ component of the function is increased in the sense that more value creation is expected as the output of the relationship due to greater commitment and information sharing.

Knowledge spillovers can be defined as any original, valuable knowledge generated somewhere that becomes accessible to external agents, whether it be knowledge fully characterizing an innovation or knowledge of a more intermediate sort (Foray, 2004). This knowledge is absorbed by an individual or group other than the originator (Appleyard, 1996; Antonelli, 1999). Spillovers measure any type of externality that is associated with the R&D activities of other firms. Spillovers have an impact on innovation output because of the imperfect appropriability of the knowledge associated with innovations. The exchanges explained above, particularly exchange of information, along with poor patent protection or reverse engineering practices, contribute to the occurrence of knowledge spillovers. The need is to define the extent to which a firm can benefit from knowledge spillovers, given that they can be both positive and negative. Positive spillovers coincide with the availability of more resources that flow thanks to the inter-firm ties that are conduits of information. Positive spillovers increase the average product of the firm's own R&D. Negative knowledge spillovers, instead, can result in the use by competitors of the firm's knowledge in ways that harm the company (Harryson & Søberg, 2009). An example is the disclosure of information, which could otherwise have been turned into valuable and strategically important IPR. Also, R&D generates two distinct types of spillover effects: technology (or knowledge) spillovers and the product market rivalry effect of R&D (Bloom et al., 2010). While technology spillovers may increase the productivity of other firms that operate in similar technology areas, the product market rivalry effect of R&D is negative for a firm's value due to business stealing. Theoretical research on the product market rivalry effects of R&D includes patent race models.

(b) L_A^{λ} component in the supply network context

This component, and particularly the λ parameter, representing the *congestion* effect, captures the dependence of research productivity on the number of people searching for new ideas at a point in time. The principle underlying this formulation is that it is quite possible that the larger the number of people seeking ideas is, the more likely the occurrence of duplication or overlap in research will be. In that case, if we double the number of researchers (LA), we may less than double the number of unique ideas or discoveries. This notion of duplication in research or "stepping on toes" placed in an inter-firm network is even more significant in the case of connections among different researchers that are competitors for the achievement of an idea or a patent and that can benefit from knowledge spillover through the ties. It is less likely for a firm to get a patent when there are many competitors who are looking for innovations and they are able to get knowledge spillovers from the firm. Of course, from the firm's perspective, the characteristics of the other researchers matter. Their presence is more harmful when they are competing for patents with applications at the same level of the value chain and when they have enough absorptive capacity to benefit from the spillovers they get. In this respect, if I am looking at the innovation output of a buyer, the result will be different, having many buyers or many suppliers that look for innovations. This is true for at least two reasons. First, there is asymmetry in the knowledge scope of suppliers and buyers such that the narrower scope of the supplier results in an inability to take advantage of the positive spillovers by exploiting them completely. Second, there is less competition for patent achievement because the types of innovations are different.

From these assumptions, I derive three main conclusions. First, the number of nodes in a network that are competing for knowledge generation and are receiving and creating spillovers is a driver of a firm's innovation output. Second, the type of nodes will determine whether the effect of positive or negative spillovers on innovation is likely to prevail. Third, the type of relation among the parties, and consequently the type of exchange and the level of adaptation in place, will determine the flow and sharing of knowledge, thus influencing innovation output. These arguments are in line with the three propositions presented in the following section.

3.1.3 Theoretical framework for the hypotheses development – Propositions

In this section, I draw on the considerations made, place them in the context of a supplier-buyer network, and propose three effects of inter-firm ties in supplier-buyer networks on firm innovation performance. They are the basis for the subsequent hypotheses development. Basically, I argue that knowledge flow in the network generates opportunities and limitations for the parties, and I assert that the final innovation output for one party depends on its capability to respectively exploit or reduce them. This capability, in turn, is a function of certain characteristics of its network that I identify by adopting both a positional and a relational approach. I briefly explain the line of reasoning behind the propositions.

As previously stated, the starting point of the arguments is the assumption that knowledge is the source of competitive advantage (Huggins & Izushi, 2007). Knowledge-based competition is the focus of the analysis. A key to successfully compete in this unpredictable race is to invest in a range of knowledge-based resources, such us collaborative relationships with other organizations. However, the relationships in industrial markets form a network creating both threats and opportunities for the development of the firms. The opportunities are represented by *positive leakiness*, meaning positive spillovers or the flow of knowledge and resources from the outside context into the firm; the threats are represented by *negative leakiness*, meaning negative spillovers or the flow of proprietary knowledge from the firm to the outside context.

I argue that indirect ties in a network have a leverage effect on both opportunities and threats. While, in a direct connection, the parties can safeguard against direct transmission of knowledge by establishing some rules about what can and cannot be discussed and shared and can protect themselves from the improper use and exploitation of the partner's knowledge, in an indirect connection, there will be intrinsically less control over knowledge transmission. If two competitors are connected directly, it is very likely that they will establish some rules to protect their knowledge. However, they can be connected indirectly through a shared firm that is a non–competitor, and they can also be unaware of the situation. If they do not set limitations on knowledge sharing even with the non-competitor (and they cannot have the interest or possibility of business reasons for doing this), they are exposed to a risk of unwanted negative spillover. Also, this specific structure can facilitate the shared partner incentives to behave opportunistically because it has control and power and possesses information that is highly valuable for the other parties. As for opportunities, of course the indirect contacts are a source of positive spillovers of a pool of knowledge and not just of a single company's knowledge. Moreover, they contribute to building the competences of the direct contacts. Also, the possibility of knowledge creation is multiplied by the potential synergies occurring in several different relationships. Therefore, it is interesting to investigate knowledge flow dynamics in indirect ties and their impact on a firm's innovation. Each relationship is frequently influenced by links of the parties with other parties: the customers' customers, the suppliers' suppliers, etc., so that the companies are embedded in networks of connected relations, the features of which influence the individual links and companies on both a collaborative and a competitive side.

The hypotheses provide insights into the benefits of indirect ties on innovation output through a contingent approach, thus contributing to advance network theory. The contingent benefits of network structure until now has been explored mostly at the individual level of analysis. At the firm level, fewer network structural contingencies have been considered (predominantly contextual factors such as the stage of industry development) (Zaheer & Bell, 2005). The supplier links the focal buyer to several nodes through indirect ties. One main question addressed in this thesis is that of when a supplier's centrality is more or less conducive to a buyer's innovation.

Network theory states that strategically positioned individuals in a network facilitate information dissemination, which, in turn, facilitates innovation. According to Burt (1997), a typical characteristic of networks influencing the likelihood of information flow across knowledge networks is centrality (Burt, 1997; Podolny & Joel, 1994). While many studies have established a causal relation between the centrality of a node and its innovation output, it is interesting to explore how the centrality of the partners of the node affects the node's innovation outcome. This, in turn, also means assessing the effects of indirect ties on a firm's innovation output. If the supplier has a central position, it has an influence on what flows and does not flow in the network: the node is important to the whole network in terms of its connective function and has the shortest paths to all others. Nerkar and Paruchuri (2005), for instance, applied Burt's (1997) hint in an organizational context, while I will apply it in an inter-organizational context. In the hypotheses formulation, I consider that a supplier's network centrality is certainly likely to positively affect the supplier's innovation output due to superior resource and information advantages. This is in line with the statement that "*the more direct ties that a firm maintains, the greater the firm's* *subsequent innovation output*” will be (Ahuja, 2000). The supplier is a node linking a firm to many indirect contacts (Haunschild, 1993; Gulati, 1995). The transfer of the benefit to the focal buyer (through an indirect tie) is an additional step. While the supplier’s benefit is derived just from the availability of more resources, the focal buyer’s benefit includes more resources and fewer knowledge spillovers. This is because, as already explained, in a dyadic relation, there is more control on knowledge flow than in an indirect tie. Also, I am investigating the impact of network characteristics of a party (supplier) on the innovation of the other party (buyer). This means that the process must involve not just knowledge sharing or flow but also the voluntary behavior of the first party (supplier) to act on behalf of the second (buyer). Drawing just on the assumption of the availability of more resources, Burt (1992) presented the aforementioned conclusion that selecting alters with many other partners is one mechanism by which an actor can develop an effective and efficient network. This does not consider the "dark side" of the social structure, meaning the leakage of knowledge and opportunism. Some contingencies should be applied. In fact, despite the considerable focus on the role of network structure in explaining firm performance outcomes, some researchers have acknowledged that a network of ties merely gives the focal firm the potential to access the resources of its contacts (Portes, 1998). The value that the firm actually derives from its contacts may also be a function of the resources controlled by those contacts and of the actors’ ability to exploit those resources.

Finally, network models have been proposed mainly through two analytical approaches, differing in the frame of reference with which an actor is analyzed (Burt, 1982): the relational and the positional approaches. In a *relational approach*, network models analyze the intensity of relationships between pairs of actors. The *positional approach* describes the patterns of relations defining an actor's position in a system of actors (Burt, 1982). My propositions and hypotheses development are built on both, analyzing the position of a node going beyond its ego-network and highlighting the role of centrality (positional perspective) as well as considering the strength of the relationships in which it is involved (relational perspective). The interaction of these two approaches will be applied, considering also the different outcomes in a cooperative and in a competitive context. In fact, from Burt's (1982) "structural theory of action," we know that the social context would constrain occupants of various positions differently in terms of their ability to pursue their interests. Actors jointly occupying a position and, therefore, pursuing similar structural interests can realize their common interests to the extent that their relational patterns ensure low competition with one other. I will, therefore, introduce the competitive element into the picture and explore how the relational approach helps in solving this structural equivalence issue inherent in the positional approach. In conclusion, I predict the following three effects:

Proposition One: A supplier's centrality determines the incoming and outgoing knowledge flow between the buyer and the supplier's partners and, hence, affects the buyer's innovation output.

Proposition Two: A supplier's centrality has a positive effect on the focal buyer’s innovation output to the extent that the context determines an *increase in positive leakiness and a reduction in negative leakiness* for the buyer. This means more available resources and fewer negative spillovers.

Proposition Three: The strength of the relationships enhances or reduces the effect of a supplier's centrality on the focal buyer's innovation depending on whether the context requires prevailingly *fostering positive leakiness or preventing negative leakiness*.

3.2 The comprehensive model

Starting with a focal buyer firm, I consider its suppliers and how each supplier’s network of ties affects the focal buyer’s innovation. The center of the network is the focal buyer; suppliers are linked directly to it, and through these suppliers, the focal buyer is linked indirectly to other suppliers or buyers. All the ties in the network involve buyers and suppliers, and they can be supply agreements, alliances, or both. The horizontal ties between two buyers are considered in the model but as a control variable (cf. chapter 5 on variable specification).

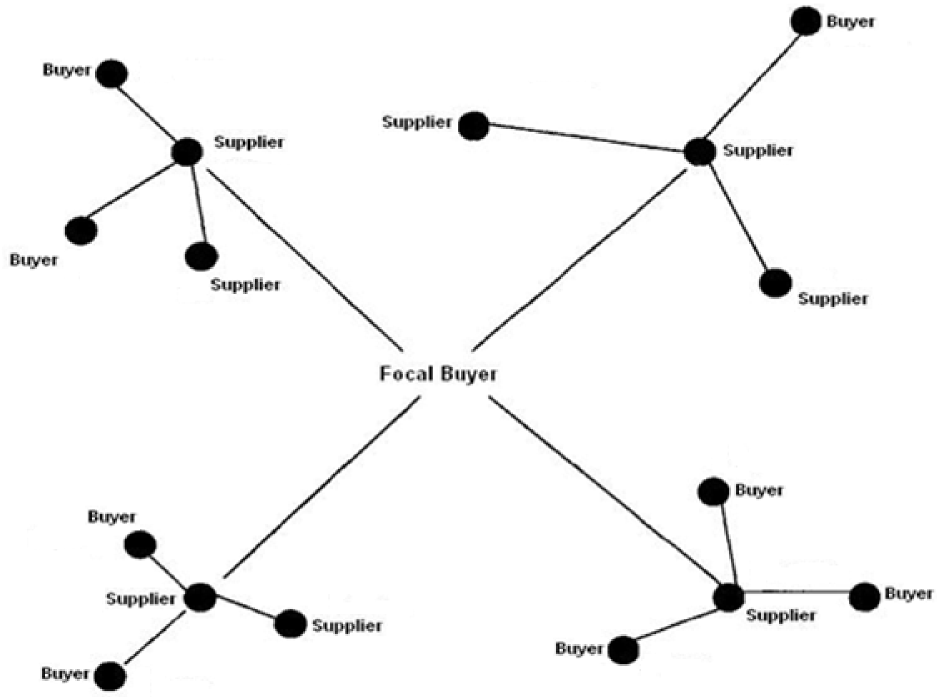


Fig. 1.1 The network

Drawing on the social capital and network theories as well as on TCE, in hypotheses, I try to understand how knowledge is connected and transferred across firms in buyer-supplier networks and to explore the conditions that maximize the sharing, creation, and exploitation of knowledge for a given firm. To identify contingencies, I focus on the properties of the nodes and of the relationships. Until now, the focus has been placed on the number of actors or on their relative positions, but an important issue to understand the implications for learning is looking at the kind of nodes to which a supplier is connected and at the strength of the relationships undertaken.

I will point out the following contingency factors: the type of actors involved in indirect ties (their role in the supply chain: suppliers or other buyers), the strength of relationships (measured in terms of the level of collaboration corresponding to a type of tie: arm's-length ties/alliances). These contingencies imply incentives or deterrents, opportunities, and risks with respect to knowledge flow and innovation. The aim is to identify the types of nodes and relations in the supplier's network that meet the conditions of increasing positive leakage and reducing negative spillovers. The number and strength of relationships shape the behavior of the nodes. Different modes of procurement with different strengths differ in terms of the extent of differentiation and integration between procuring and supplying units and, therefore, in their propensity to react to the environment in a coordinated and cooperative manner (Gulati et al., 2005). Individual nodes and their interplay in the form of competition/collaboration play an active role in advocating for the innovation of a specific buyer.

To improve clarity, I include below a schematic illustration of the analytical framework of the research. Drawing on this basis, in this chapter, I will develop four hypotheses, two about main effects and two about moderation. The model postulates that the buyer's innovation output is a function of the supplier's characteristics at the network level.

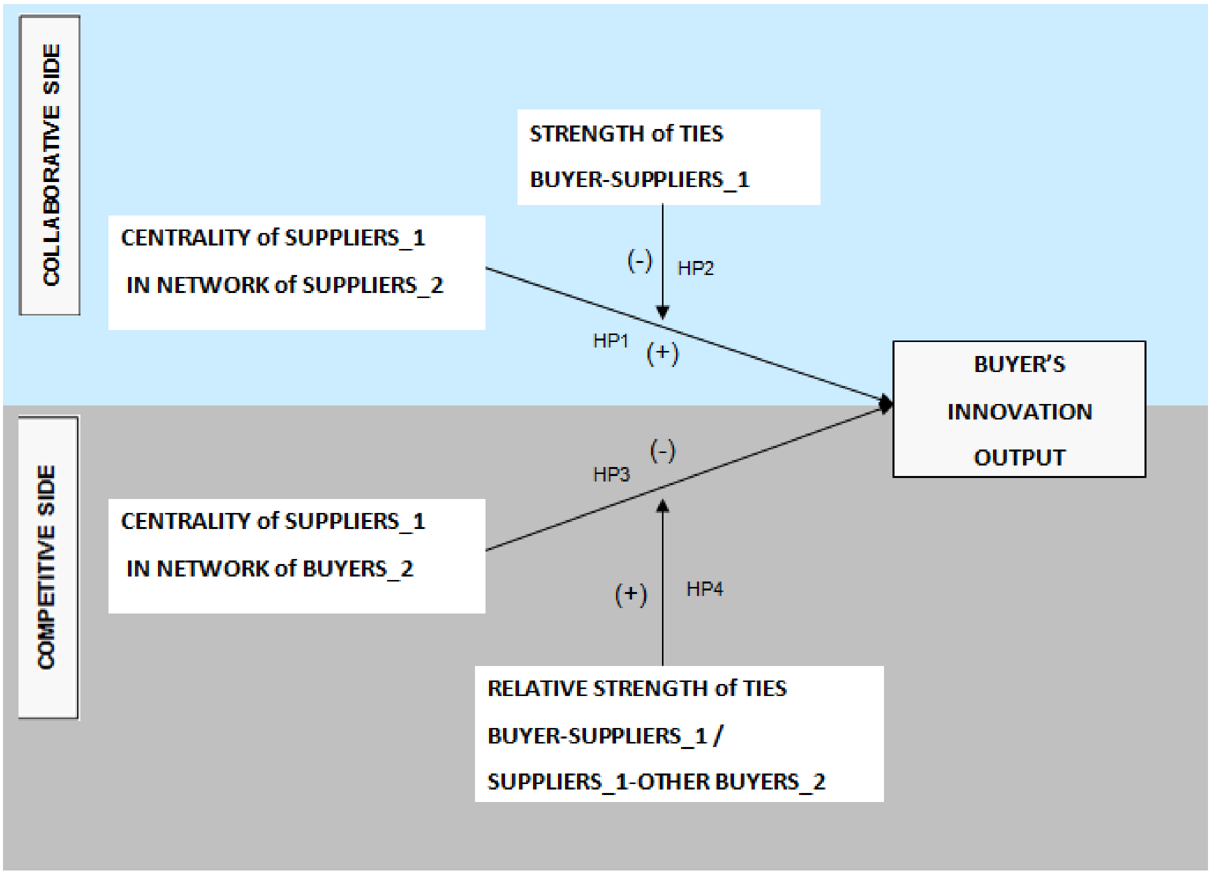


Figure 1.2 The model

When analyzing a supplier's network, two fundamental distinctions are needed between:

1) Relationships involving the upstream or downstream side of the value chain, meaning that the supplier is linked to other suppliers or to buyers. This, in turn, means that the focal buyer is linked through the supplier (in the figure, *supplier_1*) to suppliers (*suppliers_2*) that are not competitors or to other buyers (*buyers_2*), which are competitors. The predictions of the effects of

the supplier's network centrality on innovation in the two cases (in the figure, *collaborative side* and *competitive side*) constitute the main effects, summarized in hypotheses 1 and 3;

2) Relationships characterized by different strength (measured here by the kind of tie: arm's-length ties, alliances, or both). This element constitutes the moderation effects, summarized in hypotheses 2 and 4, altering the intensity of the main effects. In particular, while, on the cooperative side, only the strength at step 1 between buyer and supplier can be analyzed to infer a given impact on innovation, on the competitive side, the relative strength of the tie between the focal buyer and *supplier_1* versus the ties between *supplier_1* and *buyer_2* must be considered, owing to a context of competition.

Therefore, hypotheses also help in advancing network theory because they show that the impact of the strength of the ties on innovation is not univocal, but it depends on the context of competition or cooperation. This result is consistent with the presence of conflicting positions of different scholars, some maintaining the strength of strong ties, others asserting the strength of weak ties, as explained in the literature review. The focal buyer is related through the supplier to some nodes at distance two that can be competitors (other buyers) or non-competitors (suppliers). Depending on whether the prevailing need of the focal buyer is to defend itself by competitors located at distance two or to acquire as much knowledge is possible by non-competitors located at distance two, the strength of the ties will have a different impact, and the optimal solution will be ,alternatively, strong ties or weak ties, in the first case to improve commitment and avoid opportunism and in the second case to increase the exploitation of ideas by the buyer and the supplier's openness in avoiding the lock-in negative effect. Therefore, a contingent approach is needed to evaluate the effects of the strength of the ties on innovation: in the presence of competition for the information, the strength of strong ties prevail, while in the absence of it, weak ties win. This is somewhat parallel to the contingent approach presented by Ahuja (2000) to interpret the impact of structural holes on innovation: it is negative in the case of direct collaboration among competitors that requires cohesion, while it is positive in the study of Hargadon and Sutton (1997), where a consulting firm served its clients with innovative ideas.

3.3 The collaborative dimension in buyer-supplier networks and knowledge-flow

This section is based on the collaborative side of the supplier-buyer network. I focus on the case in which the indirect nodes reached by the buyer through the supplier are not competitors but other suppliers. I investigate the impact of the supplier's centrality in its external network of other suppliers on the buyer's innovation output.

3.3.1 Hypothesis one - The supplier's centrality in the network of suppliers

I predict that the supplier's centrality in its network of suppliers will enhance the buyer's innovation output, as measured by patenting frequency. Innovation depends on the knowledge flow to ego. First, a basic assumption is that the knowledge transfer from the alter (supplier) to the ego (buyer) and the other way around occurs through the contact points between the supplier's value chain and the buyer's value chain that provide several opportunities (Porter, 1985) or through an alliance tie with cooperation. In the first case, the buyer firm's inbound logistics share an interface with the supplier's order entry system, the supplier's applications engineering staff works with the buyer's technology development group, and the supplier's finished goods inventory is linked to the buyer's work-in-process. The business world abounds with examples of firms that have exploited one or more of these linkages effectively. In the second case, there is joint involvement in manufacturing or R&D.

The knowledge flow extends beyond the direct tie. Therefore, the position of the supplier in its network matters. As explained above, two competing factors determine whether an alter's centrality determines an increase in the ego's innovation or not: positive knowledge leakage and negative knowledge spillovers. I argue that, when the ego is a buyer and an alter that is a supplier is central among suppliers, positive knowledge leakage is enhanced and negative knowledge spillovers are reduced. As stated in proposition two presented in the previous section, the occurrence of these two conditions will result in a positive effect of the alter's centrality on the ego's innovation output. I next elaborate on these two factors, identifying the main mechanisms contributing to each of them.

(a) Increase in positive leakage

The increase in positive leakage is determined by several mechanisms. I identify them with the supplier's gatekeeping role; the availability of a wider pool of knowledge coming from the individual connected actors and from their interactions, i.e. technical embeddedness; the increase in the supplier's capabilities; the availability of better products; the scale effect; the exploitation of horizontal ties' benefits; and the option of transitivity. I next examine each of them.

The suppliers are reached indirectly by the buyer through the supplier. The supplier in this case assumes the role of *gatekeeper,* opening access to a wider network of suppliers. This is critical to importing information from the outside context and to linking the organization with its environment (Allen, 1977). High centrality leads to a higher volume and rapidity of flows of information and opportunities so that the central supplier enhances knowledge mobility. Consequently, through it, indirect ties provide access to knowledge even if they do not provide formal resource sharing benefits (as direct ties) (Ahuja, 2000). The identification of an entity that performs the gatekeeping functions serves as important support for innovative activities (Allen, 1977). For instance, as a parallel in an intra-organizational context, functions that serve as channels for the communication of technical information between sources outside their organization and those inside have been shown to be critical in suggesting new ideas and in bringing relevant information to bear on innovative efforts.

This structure allows reliance on a wider pool of product and process technologies during the innovation process, even if it is indirect. There is a wider information base that flows from the external pool of suppliers through the supplier. The additional knowledge capital comprises two components: (1) the single knowledge of the supplier's contacts and (2) the knowledge created from the synergies achieved in the relationships with these contacts. As for the latter, the supplier benefits from a specific form of embeddedness: technical embeddedness, which is defined as the "interdependencies between firms in terms of their product and production development processes" (Andersson, Forsgren, & Holm, 2002). In these interdependencies in the supplier-supplier relationships, new valuable knowledge is likely to arise and this, in turn, can be transferred to the buyer.

The capabilities and competences of the supplier directly linked to the buyer are presumed to be the result of its relationships also. The process of knowledge accumulation will be higher on the part of the supplier, which will be, consequently, a more qualified partner with greater experience. The supplier has more learning opportunities; it is likely to be a knowledge broker. Furthermore, considering that networks promote innovation indirectly by facilitating increased specialization and division of labor, which leads to more focused expertise development (Piore & Sabel, 1984; Saxenian, 1991), a supplier with a wider network can also benefit from this positive aspect.

Considering another dimension of the situation, the greater knowledge will also be embedded in the supplier's products. They have a higher likelihood of incorporating the innovations, the advancements present in components coming from a high number of different firms, which are sources. These products will, in turn, be incorporated in the buyer's final product, leading to greater innovation output.

Having many indirect ties also allows a node to enjoy the benefits of network size without paying the costs of network maintenance associated with direct ties (Burt, 1992). There is a leverage effect in action. The supplier can benefit from the scale effect, and, in turn, this will also be positive for the buyer. The scale effect influences innovative output, affecting the transformation function *f* of the innovation function. Basically, if technology has increasing returns to scale, increases in inputs are rewarded with more than proportionate increases in output. The scale effect is more likely to arise in supplier-supplier relations (and, hence, when the supplier connected to the buyer is central among suppliers). This because a precondition for the occurrence of increasing returns to scale is the collaboration between firms providing similar inputs. In fact, ties where the partners bring in similar assets or competences are called scale linkages (Hennart, 1988). Scale alliances are horizontal alliances in which all partners contribute similar resources and assets (Garrette et al., 2007).

The supplier can have a supply tie, an alliance tie, or both with the other suppliers. This means that it will benefit both from horizontal and vertical ties, and these resources will, in turn, be advantageous for the buyer. A horizontal tie between two suppliers can be really advantageous in terms of R&D outcomes. This is evident also considering the increasing tendency of buyers in managing their supply chain by fostering linkage creation among their own direct suppliers. It is true in that specific case that their aim is to increase competition among the suppliers, but they are also driven by knowledge generation reasons. From this perspective, in my specific case, the positive effect on the buyer can be even greater considering that one of the two suppliers is out of the buyer's sphere of influence and should possess different applied knowledge.

It is also possible that the buyer will have more possibilities to widen its suppliers' base, if needed. This is due to the transitivity phenomenon: if two organizations are linked to a common third party, there is an increased probability that they will establish a relationship. The origin of transitivity has been traced back to the structural embeddedness – the presence of common partners has been suggested to facilitate the formation of direct relationships between nodes – and to information flow; the third party transmits information between its partners about their skills and capabilities (Gulati & Gargiulo, 1999). Therefore, the buyer could potentially benefit from the opportunity to identify suppliers of known quality easily, if needed. This constitutes an additional option to increase its innovation output.

(b) Reduction in negative spillovers

The reduction in negative spillovers is determined by two main factors. First is the absence of competition between the buyer and the indirect partners; second is the low level of absorptive capacity of the indirect partners. I briefly examine both.

First, the nodes linked through the indirect ties (the focal buyer and the suppliers of its suppliers) are located at a different level of the value chain, and they are not competitors. This means that the focal buyer benefits from the suppliers' deep specialization (capabilities, experience, and innovativeness developed by suppliers) and, at the same time, does not experience the negative effect of competition in innovation or the patent race. The patents of suppliers and buyers revolve around different knowledge applications. Also, the control of a particular market is a kind of complementary asset that is essential to the exploitation of an innovation (Foray, 2004). More specifically, the negative spillovers will be still in place, but their exploitation is not likely to be harmful. It is true that these indirect suppliers can be, in turn, related to other buyers, thus having opportunities to exploit these spillovers, but the effect will be weaker, perhaps even unperceivable. The path is longer, so the effect is weaker.

Second, I argue that the detrimental exploitation of the buyer's negative spillovers is limited by the low absorptive capacity of the indirect partners when they are suppliers. This is due mainly to the asymmetry in the knowledge scope between buyers and suppliers. While the assembler needs to have a comprehensive and complex knowledge of the products, it must adopt a perspective of integration and combination, and the scope of the supplier's knowledge is narrower. The assembler's knowledge is at an aggregate level, so it is less exploitable by a supplier, which typically has specialized knowledge. The exploitation of new knowledge requires specific capacities that the inventor has, such as technological capacities needed to implement the innovation. Even if others appropriate the idea, only those who have the needed capacities are able to exploit it (Foray, 2004).

For the aforementioned reasons, in the case examined, the externality is likely to be artificial. Although knowledge is diffused, the benefits associated with its implementation remain internal. Therefore I can assume a final positive effect on the innovation output and I can formulate the following hypothesis.

HP 1: ***The higher the supplier's centrality in the network of suppliers, the higher the buyer’s innovation output***

3.3.2. Hypothesis two - Moderation of the strength of ties

Here, I analyze how the impact of tie strength can amplify or reduce the main effect showed in the previous hypothesis. To increase the effect of the supplier's centrality in a network of suppliers on a buyer's innovation output, a further increase in positive leakage can be useful. I am considering here a cooperative context in which nodes indirectly linked to a motor vehicle company are not its competitors; the competitive dark side of centrality is absent. The context requires more to foster positive knowledge leakage than to prevent the knowledge spillover that is already not taking place. This, as stated in proposition three presented in the previous section, helps in determining the influence of the strength of the ties. I next explain why.

(a) *No need to prevent negative knowledge spillovers. Consequences.*

From the TCE perspective, I derive the notion that a strong tie, as an alliance or hybrid organizational form, functions mainly as a means to prevent the "negative," as a defense mechanism to tackle the problem of strategic uncertainty. I can argue that this strategic uncertainty is lower in the specific context considered here. Hennart (1988) stressed that an alliance is not successful if it cannot be transformed to help reduce behavioral uncertainty and consequential requirements for the sake of monitoring. Along a similar line, Kogut (1988) demonstrated that high levels of uncertainty stimulate the formation of joint ventures when a firm’s performance is critically affected. From this argument, I can conclude that there is no incentive to establish a strong tie.

(b) *Need to foster positive knowledge leakage. Consequences.*

I am looking at indirect relationships comprising two steps: one step from the ego to the alter (internal direct tie) and the other step from the alter to the alter's alters (external network). To enhance the positive knowledge leakage flowing from the network toward the ego, two mechanisms must occur: (1) the increase in the alter's knowledge accumulation from the external network and (2) the increase in the capability and opportunity of the ego to appropriate and exploit the alter's knowledge through the direct tie. There is a condition that allows the achievement of both, even involving just one step of the indirect relationship: the presence of a weak tie between ego and alter (internal direct tie).

This is the case at least for two reasons. First, in the internal direct tie, this allows the opportunistic behavior of the ego to exploit the alter's knowledge and involves informal forms of knowledge transfer. The informal contact points can have positive effects on ego innovation. Second, in the external network, it avoids the lock-in effect and favors the openness of the alter to the network. I next explain these points.

First, the TCE perspective can be applied to catch the advantages of the opportunistic behavior of the focal buyer in the direct tie with the supplier. Buyers can adopt actions and practices that reflect a short-term mentality in regard to pricing, warranty, and intellectual property. Suppliers often voice their objections to the opportunistic methods and behavior used by buyers. Some manufacturers demand that suppliers contractually waive their rights to intellectual property (unless patented) and will shop the technology at the first opportunity. In this way, they can exploit more innovations developed by different suppliers. This means that they can get opportunistic advantages from the presence of a weak relation. One could argue that this opportunism can be applied also by the supplier, who may take advantage of the buyer's knowledge. However, as explained in the previous hypothesis, the possibilities for exploiting buyer's knowledge in a harmful way are lower for the suppliers unless they are linked to other buyers, and this is not the case under analysis.

Moreover, a weak tie allows fewer rules and the transfer of knowledge in informal ways. I am considering as stronger ties alliances that are formal agreements between two parties. The relative importance of informal networking is highlighted by several authors (e.g. Senker & Faulkner, 1996; Kreiner & Schultz, 1993), even if it seems to be in opposition to the current fashion for formal collaboration. In this connection, MacDonald (1992) suggested that formal collaboration may actually undermine the informal information networks on which firms rely. In fact, some types of tacit knowledge are quite extensively shared through informal interaction. This is in line with Granovetter's (1973) concept of the strength of weak ties, according to which the most valuable knowledge flows generally take place as a result of the least visible forms of networking.

Second, the strength of weak ties seems to be essential in managing the risks of lock-in or hold-up. If organizations concentrate too narrowly on the existing relationships (strong ties) and are unable to take a broader view on the environment in which many trends, driving forces, and scenarios arise, they are less likely to be able to respond effectively to the changing needs and requirements. To get effective innovation results, the availability of different knowledge sources and the openness of the central nodes to new ideas are the most relevant elements. If the supplier becomes too tight with the focal buyer, its absorptive capacity, useful for catching knowledge from the external actors, is likely to drop. Cohesive network structures may limit the capability of the adaptation of an actor to changes in interdependencies as the strength of ties enhances the pressure on actors to maintain non-advantageous ties due to the amplified reciprocity mechanism, with a limitation of the ability to establish new ties (Soda & Usai, 1999; Gargiulo & Benassi, 2000). Uzzi (1997), in his work on the paradox of embeddedness, shows how overembeddedness can ossify the network and keep it locked away from the demand of its environment, leading to a decline in its performance. This suggests that strategic networks composed mostly of strong ties may threaten innovation rather than enhance it. The problem is the opposite of the free-rider problem: diligent commitment, combined with expectations of reciprocity and social pressure to perform, intensifies an organization's involvement with certain network partners while raising the concomitant costs of maintaining ties to extra-network partners. Portes and Sensenbrenner (1993) drew attention to this phenomenon in their study of entrepreneurs, whose socially embedded relationships gave them access to resources but restricted their actions outside their network. This line of reasoning is consistent with the literature examining the negative consequences of social capital, according to which social ties imprison actors in maladaptive situations (Gargiulo & Benassi, 1999; Gulati & Westphal, 1999; Portes & Landolt, 1996; Putnam, 2000; Volker & Flap, 2001). Therefore, the benefits arising from embeddedness (Granovetter, 1985), consisting of higher trust, fine-granted information transfers, joint problem-solving arrangements, and adaptation, fall when actors in the network are too connected by embedded ties. The strength of weak ties relies on the potential of weak ties to foster and accelerate innovation by connecting a focal firm to otherwise difficult-to-reach knowledge areas (Rogers, 2003). By adding weak ties to its network, a firm is likely to add non-redundant contacts and, hence, expand network diversity (Burt, 1992), increasing its innovative outcome.

In conclusion, I consider the interaction between a firm's centrality and the strength of the ties surrounding it. Since I am examining the impact of a supplier's centrality on a focal buyer's innovative performance and the indirect nodes are not competitors, I focus particularly on the strength of the tie linking these two actors. If the supplier is too much involved and locked into the relationship with the focal buyer, it is likely to have a lower chance of developing experience and investing in asset specificity and less commitment in its own external relationship. This means that its role of gatekeeper will be dampened. The strong tie reduces opportunism in the direct tie (positive for the buyer) and limits the search for knowledge in the external network. Therefore, I can argue that the weaker is the tie between the focal buyer and the supplier, the more beneficial the supplier's centrality in a network of suppliers (and, hence, the availability of a wider pool of resources) will be. The focal buyer can behave opportunistically and exploit the benefit, and the supplier is more open to its external network consisting of a high number of nodes to accumulate potential incoming knowledge. Therefore, I can formulate the following hypothesis:

HP 2: ***The impact of supplier's centrality in the network of suppliers on buyer's innovation output is moderated by the strength of the buyer's direct tie with the supplier:***

the higher the strength of the buyer's direct tie with the supplier the lower the positive impact of supplier's centrality in the network of suppliers on buyer's innovation output.

3.4 The competitive dimension in buyer-supplier networks and knowledge flow

This section is based on the competitive side of the supplier-buyer network. I focus on the case in which the indirect nodes reached by the buyer through the supplier are competitors. I investigate the impact of the supplier's centrality in its external network of other buyers on a buyer's innovation output.

3.4.1 Hypothesis three - The supplier's centrality in the network of buyers

I predict that the supplier's centrality in its network of buyers will reduce the buyer's innovation output, as measured by patenting frequency. Innovation depends on the knowledge flow to the ego. As explained above, two competing factors determine whether an alter's centrality facilitates an increase in the ego's innovation or not: positive knowledge leakage and negative knowledge spillovers. I argue that, when the ego is a buyer and the alter that is a supplier is central among buyers, negative knowledge spillovers are enhanced, and they are able to overcome the benefits of positive knowledge leakage, which are also partially reduced in this case. As stated in proposition two, presented in the previous section, the occurrence of these two conditions will result in a negative effect of the alter's centrality on the ego's innovation output. I next elaborate on these two factors, identifying the main mechanisms contributing to each of them.

(a) Increase in positive leakage at a decreasing rate

Suppliers of parts and components will actively seek to supply more than one producer. From a network perspective, this implies that it is likely to have out-stars in the supply network, i.e. structures in which a supplier is connected to multiple producers (Lomi & Pattison, 2006).

Nobeoka et al. (2004) demonstrated that, from the point of view of the supplier, a broad "customer scope strategy" leads to superior performance because of learning opportunities. They predicted a positive relationship between the number of a supplier's customers and the supplier's knowledge. This is the positive effect on the supplier. This means that, potentially, the buyer can benefit from a more experienced supplier and from a wider pool of knowledge. However, in the context of competition among the indirectly linked nodes, additional elements should be taken into consideration. As presented in the section on the innovation function, there is a *congestion* effect, represented by the λ parameter, which explains how the larger the number of people seeking similar ideas is, the more likely the occurrence of duplication or overlap in research will be. An increase in the number of researchers corresponds to a less than proportionate increase in the number of unique ideas or discoveries. Therefore, there can easily be duplications between the focal buyer's knowledge and other buyers' knowledge, and this can reduce the positive impact of the flow of knowledge to the focal buyer.

This congestion effect occurs and is significant, having an impact on the focal buyer's innovation output (patenting frequency), to the extent that the focal buyer and the alters are looking for similar innovation at the same level of the value chain. This was not the case in the presence of suppliers in the indirect relationships because that kind of specialized knowledge was just enriching the technical basis for further development and application by the buyer. This notion of “stepping on toes” is clearly enhanced in the case of connections in an inter-firm network where researchers are competitors for the achievement of an idea or a patent, meaning that they are working on similar ideas and there is knowledge spillover through the ties. The latter element, the increase in negative spillovers, is examined next.

Moreover, while it is quite natural for a supplier to transfer the knowledge it gets from other suppliers to a buyer, it is a less obvious matter to transfer the knowledge it gets from other buyers to a buyer. The buyers, from the perspective of the supplier, are, in principle, all comparable actors at the same level. The supplier must have an incentive to behave on behalf of one buyer more than in favor of another buyer given the detrimental effect that this knowledge transfer can have for one of its partners. In this case, it could be more appropriate to say that there is a certain degree of potential stickiness in the flow of knowledge.

(b) Increase in negative spillovers

A supplier having relationships with buyers of the same industry creates problems of *negative leakiness* (Bengtsson & Eriksson, 2002) due to competition. Each tie represents for the actor a source of information and resources but also a weak point through which knowledge and resources could drain (Gnyawali & Madhavan, 2001). If the supplier operates in a non-exclusive way, innovations developed inside the industry can be transferred to all competitors, and we cannot conjecture regarding who benefits from innovation. Strategy theorists often see firms as antagonists seeking to appropriate the profits of existing business activities in an industry. They have described the search for competitive advantage as a distributive game (Williamson, 1975; Porter, 1980). The business press has coined the term “pie expansion” to refer to the collaborative process of creating mutually beneficial strategic outcomes between buyers and suppliers, originally considered to be antagonists (Jap, 1999). However, I suggest that this expansion can be dampened by the presence of competitors as indirect nodes linked to the firm.

The increase in the effect of negative spillovers, meaning here the negative exploitation of the knowledge flowing from the focal actor to the network and leading to a negative impact on the buyer's innovation output, is determined by several mechanisms. They are basically the patent race, the saturation process in patent generation, the supplier's power and dependence. The latter element determines not only the level of spillovers but also introduces the argument of the supplier's commitment. Moreover, it is related to Bonacich's (1987) distinction between centrality and power. I elaborate on these factors.

First, from the patent race literature, we know that firms compete to develop and bring to market a product and that only the first mover makes a profit on the innovation. The discoverer, by patenting the innovation, can bar others from exploiting that idea (Baiman & Rajan, 2002). Here, the *timing* benefit of networks identified by Burt (1992) assumes a crucial meaning. The network is a locus for the early diffusion of ideas that will, in turn, take years to become common knowledge. In many industries, the temporal lag between the invention and its official diffusion through patents can be significant (Almeida & Kogut, 1995), and some inventions are also not patentable at all. The network allows the unofficial disclosure of these inventions. Therefore, the likelihood of having an invention exploited is reduced with the increase in the number of competitors. We are analyzing a typical zero-sum game, where the participants are struggling over a fixed asset and one player's gain is the other's loss, as shown by game theory. The common objectives create competition among actors, even if the single project is part of a larger, more cooperative game (Morris, 1992; Powell, 1999; Brams, 1994; Axelrod, 1984). It seems important to introduce this perspective in the study of social networks also considering that the role of the business firm, as the central institution through which innovation is commercialized, does not receive the same emphasis in the sociology literature as in the economics of innovation literature (Coombs et al. 1996).

Second, the literature on patent generation states that each new patent requires a certain amount of new knowledge, and the closer the scientists get to the maximum number of patents achievable in their field, the more difficult it is for them to do further related research (Kapmeier, 2006). The relationship with the shared supplier tends to create a common knowledge base between the competitor buyers that, in some way, enhance and speed up this saturation process.

Third, another argument to evaluate the effect of the supplier's centrality among buyers on the focal buyer's innovation is one of power or dependence: in the presence of a smaller number of buyers, the supplier is more dependent on buyers, and it can be more willing to spur innovation. A network composed of relationships with partners with few ties to others will facilitate control over exchange partners, and this, according to Porter (1985), is the objective of a firm seeking power over its suppliers. The supplier firm's dependence on the buyer-supplier relationship plays a crucial role in determining the commitment of the supplier to the focal buyer's innovation: a highly dependent supplier would be expected to have a substantial commitment to innovation. For a highly dependent supplier, the commitment to innovation could be based on the intention to retain the focal buyer's business and on the potential power of innovation in opening new technological/market occasions and, consequently, in reducing its dependence. On the contrary, a supplier firm with a low level of dependence on a buyer-supplier relationship is a company operating in many projects, with a technological structure that is more complex than that of a highly dependent supplier. Such a company, with its experience in managing more than one technology/market simultaneously, is likely to be less responsive to the focal buyer's efforts to control technological input within a buyer-supplier relationship. This leads to the suggestion that the dependence of a supplier on a focal buyer-relationship influences its commitment to innovation that, in turn, is a determinant of a focal buyer's innovative activities. Therefore, according to this line of reasoning, the higher is the centrality of the supplier among other buyers, the less the supplier is dependent on the single buyer, the lower the supplier's commitment to focal buyer's innovation and the higher the opportunistic behaviour propensity will be. Consequently the focal buyer's innovation will be lower. On the contrary, if centrality is lower, the incentive to behave opportunistically and the negative knowledge spillovers through the shared supplier will be reduced.

In the literature, the negative sides of centrality are usually outweighed by the benefits that the central actor gains through occupying privileged positions; the literature refers, indeed, to the bargaining power retained by the central actors (Burt, 1992) and to information flow. Just a few contributions have highlighted that this balance is undermined by situations in which the actors are not only related by cooperative relations but also by competitive dynamics (Gnyawali & Madhavan, 2001; Dhanaraj & Parkhe, 2006): as noted by Burt (1992), the position alone does not create the benefit, as the advantages are determined by the entrepreneurial behavior of the actor. This remark is even more significant in the specific case I am analyzing. The perspective of my analysis is different: I am investigating the effect on a firm's innovation output not of its centrality but of the centrality of its partners (suppliers). The centrality of the firm's partners is often considered to be equivalent to the centrality of the firm, but I am questioning this assumption by showing that it is contingent on the type of actors related to the central actor linked to the focal firm and to the types of ties in the network of this central actor. This argument is, in some ways, in line with Bonacich's (1987) distinction between the concept of centrality and power. He highlighted that being related to a central node can be both positive and negative. Bonacich (1987) asserted that a node may be considered central if it is connected to nodes that have connections to many other nodes; a node may be considered powerful if it is connected to nodes that have connections to few other nodes (Hanneman & Riddle, 2005). Bonacich's (1987) basic principle is that, in bargaining situations, it is advantageous to be connected to those who have few options; power comes from being connected to those who are powerless. Being connected to powerful others who have many potential trading partners reduces one's bargaining power (Bonacich, 1987).

Therefore, the aim is to test whether, in a competitive context, the negative effects of centrality are likely to outweigh its benefits or not. Our prediction is that the supplier's centrality in the network of other buyers negatively affects the buyer’s innovation output. Hence, I formulate the following hypothesis.

HP 3: ***The higher the supplier's centrality in the network of buyers, the lower the buyer’s innovation output***

3.4.2 Hypothesis four - Moderation of the relative strength of ties

I analyze how the impact of the strength of ties can amplify or reduce the main effect shown in the previous hypothesis. To increase the effect of the supplier's centrality in a network of buyers on the buyer's innovation output, the reduction of negative knowledge spillovers is crucial. I am considering here a competitive context in which the nodes indirectly linked to a motor vehicle company are its competitors. The context requires mainly prevention of the negative knowledge spillover, and as an additional element, enhancement of the positive knowledge leakage. This, as stated in proposition three, presented in the previous section, is the basic principle to determine the influence of the strength of the ties.

When analyzing the downstream side of the chain – relationships between suppliers and other buyers – it becomes more important to consider the strength of the ties (depending on the type of tie) because we have to deal with supplier-mediated competition. To find a solution that ensures a certain benefit to the focal buyer in the context of competition, I can focus on the relative strength of the focal buyer-supplier versus supplier-other buyers ties. This is the basis for formulating the hypothesis. In fact, the central actor can be of strategic importance to networks of innovators by playing a pivotal role in ensuring an equitable distribution of value (Dhanaraj & Parkhe, 2006). This means that, in the context of competition such as the one I am analyzing, the type of relationship that each competitor establishes with the central supplier matters because it can be determinant in shaping the supplier's behavior. Since my dependent variable is focal buyer innovation, I should pay attention to the relationship between the focal buyer and the supplier, and, at the same time, I should analyze the relationships in the supplier’s external network of vertical ties. It is evident that the focal buyer payoff depends on the focal tie (focal buyer-supplier) and on the supplier's other ties, considered in a relative perspective.

The general reasoning I can present is that, when information flow is dense, the relative strength of ties matters. The less exclusive the relationship of the focal buyer with the supplier is – meaning that that the supplier is connected to many other buyers – the more a strong tie helps. In other words, the marginal return of a strong tie is higher. I can analyze the case in greater depth.

The line of reasoning underlying the hypothesis is developed as follows. First, I examine how the different characteristics of weak and strong relationships have an impact on a buyer's innovation in a context like this. On this basis, I identify the optimal solution in terms of the strength of the ties and, finally, I show that this solution is the one that allows the prevention of negative knowledge spillover and the fostering of positive knowledge leakage.

(a) *Impact of the characteristics of weak and strong relationships on buyer's innovation*

Let us start by considering the context of all weak ties, meaning, in our specific perspective, arm's-length ties. Supplier-mediated competition is more likely to arise when buyers and suppliers operate based on a short-term relationship orientation. With this relationship, the supplier could increase its business, receive information on competitors, and learn general process information that can be used in customer relationships elsewhere (Jap, 1999). The standardization of products causes potential exploitation and facilitates the patent race among buyers. Weak ties are typically characterized by non-specific investments, minimal information and coordination mechanisms, and low interdependence between actors (Dyer & Singh, 1998); therefore, the content and the outcomes of the relationships are easily *imitable*. A supplier's innovation can be incorporated in a higher-quality unit manufactured by it and sold to all the buyers. In the continuum between make and buy, we are located near the "buy" option; the supplier's resources are available for all the actors, with a greater concern for the appropriability of innovation developed thanks to the supplier. Relying on the TCE literature, we can assume that, in the case of arm's-length supply transactions, there is a higher level of opportunism and potential misappropriation of information, also characterized by lesser legal bonds. Moreover, actors' behavior is more likely to be *efficiency-driven*. The buyer can demand price reductions; a supplier may reduce the resources invested in the buyer's business to balance its effort and gains (Hatfield et al., 1979). Therefore, we can presume that, in the context of all weak ties (both in the focal buyer-supplier tie and in the supplier-other buyers ties), the centrality of the supplier in a network of other buyers has a negative impact on the buyer's innovation output.

When we consider a strong tie (introducing, in our specific case, an alliance), new positive elements are involved: idiosyncratic, dedicated, specific investments, customized products, and the aim of creating mutual beneficial strategic outcomes. This is clear if we consider that vertical alliances differ from traditional supplier-buyer relations mainly in the following attributes: (1) the participation of the supplier in the new product design from the beginning and not at a later stage and (2) the responsibility for an entire subsystem of the product, not just for the production of a basic component on the basis of a full set of specifications drawn up entirely by the buyer

(Dussauge & Garrette, 1999). In a cooperative relationship, the companies have a long-term relationship commitment and share common goals. Factors that induce the supplier to act on behalf of the buyers can be detected both on the input side and on the output side of the relationship.

Regarding *inputs*, we can consider the *supplier's relation-specific investments*; they are the *adaptation processes* mentioned in the first section of the chapter. They are unilateral commitments made by the supplier, ranging from tangible assets to intangible resources, to ensure the achievement of collaboration goals (Wang et al., 2001). They lose their value outside the relationship and, therefore, have relationship-stabilizing properties (Jap, 1999). The literature shows that a supplier's investment in relation-specific assets will have a positive effect on the supplier's dependence (De Jong & Nooteboom, 2000; Bensaou & Anderson, 1999). As explained previously, this will have a positive impact on joint actions (Kim et al., 1999; Zaheer et. al., 1998) and, consequently, on a buyer's innovation output. Regarding *outputs,* Sako (1994) suggested that suppliers are more likely to innovate if they think they will get a share of the benefits. With an alliance, there are *common aims* and expectations, and we know that the optimal structure of inter-firm networks depends on the aims of the network members (Ahuja, 2000). The supplier is likely to get lasting benefits from the buyer's success.

In sum, with an alliance, the three dimensions of social capital are increased: (1) the relational one (trust, identification, obligation, commitment); (2) the cognitive one (shared ambition, vision, values); (3) the structural one (strength and number of ties between actors). These elements are useful in minimizing opportunistic behavior and spillover effect. In particular, Carey et al. (2011) argued that relational capital is positively associated with buyer innovation improvement and mediates the cognitive capital-buyer innovation improvement relationship and the social interaction ties-buyer innovation improvement relationship. According to the authors, relational capital (trust) helps in favoring the sharing of cognitions between buyer and supplier, which are required for innovation. Reducing the concerns associated with information sharing, it encourages buyers and suppliers to act on their shared vision, ambitions, and goals. Also, in social interaction ties (during social events or when working in teams), the parties share information about opportunities for innovation. Relational capital acts as a form of assurance to both parties facilitating the process (Carey et al., 2011). In conclusion, if alliance means higher relational capital and relational capital means higher innovation, for the transitive law, alliance should result in greater innovation.

If the strength here is measured in terms of the type of tie, where the highest strength is the combination of alliance plus supply, the maximum strength also includes multiplexity. Multiplexity is the occurrence of different types of ties between two nodes (Carrington et al., 2005) or the overlap of roles, exchanges, or affiliations within a social relationship (Zerbini & Castaldo, 2007). The supplier has two distinct roles, that of a seller and that of a partner. The structural dimension of social capital is increased here. Referring to RBV theory, it is possible to argue that multiplexity is a valuable resource that is rare and difficult to imitate or substitute. The reason for this can be found in network theory in sociology. The presence of multiple kinds of relationships gives greater stability, enforcing each relationship. An actor has more difficulties in breaking a tie if it has also another tie with the same partner.

What I have explained until now supports the notion that a supplier will act on behalf of a buyer and that the relationship is effective and favors innovation. However, we have several customers with the same supplier as a partner; all the buyers linked to the supplier will potentially benefit from this situation. My aim is to identify the situation in which the payoff for the focal buyer will undoubtedly be positive. The certainty for a positive result is given by an advantage in strength: a focal buyer-supplier tie that is stronger than supplier-other buyers ties. Hence, the optimal case is the one in which a strong tie links the focal buyer to the supplier and weak ties link the supplier to other buyers. This option allows the prevention of negative knowledge spillovers and the fostering of positive leakiness, as I explain next.

(b) *Need to prevent negative knowledge spillovers*

On one hand, the strong focal buyer-supplier tie permits the occurrence of positive "stickiness" (Bengtsson & Eriksson, 2002) and, therefore, a reduction in negative spillovers. The most obvious reason is that, from TCE, we know that a strong tie is a tool to establish enforcing mechanisms that protect against knowledge spillovers and opportunistic behaviors. A reduction in transaction costs can be achieved in this way.

The second reason is that it is likely that the elements characterizing a strong tie are the foundation for inimitable aspects of the collaboration process and outcomes. From the RBV theory, I posit that the content of a strong relationship becomes not easily transferable to other ties due to the specialization of the relationship (unlike weak ties). Inter-firm specialization is a source of relational quasi-rents and competitive advantage (Dyer, 1996). Coordination efforts and idiosyncratic investments make it possible for firms to combine their resources in unique ways (Jap, 1999). We know that, in RBV theory, unlike TCE, there is not a focus on the avoidance of opportunism: the firm is seen as a “creator of the positive,” of rare inimitable resources, rather than an “avoider of the negative” (Prahalad & Hamel, 1990). However, here, I want to stress that it is just this uniqueness that prevents negative leakiness. A strong tie engenders cooperation, mutual trust, and understanding based on common norms or behaviors: intensive, repeated interactions. They foster a normative environment against opportunism that raises barriers to resource mobilization and competitive practices (Obstfeld, 2005).

Furthermore, the greatest strength is characterized in my network by multiplexity. As pointed out by Tuli et al. (2010), the benefits of this multidimensional interaction are solidarity and private information. Regarding solidarity, “multiplex relationships are more stable because it is more difficult to terminate a relationship comprising diverse ties in which each type of tie provides unique value for the partners” (Tuli et al., 2010). Relationships with high solidarity are viewed as entry barriers that are “almost impenetrable by rivals” (Tuli et al., 2010). There is greater commitment and reciprocity toward each other. Multiplexity in networks becomes, in this way, a mechanism to avoid opportunism. Acting unethically toward another party increases the costs involved in breaking the relationship; therefore, multiplex relationships are typically strong relationships (Brass et al., 1998). Moreover, multiplex relationships allow also greater idiosyncratic solutions and specific commitment on the part of the supplier because the parties know each other from different perspectives and get richer and non-redundant information from the different kinds of ties. This relation-specific approach prevents knowledge spillovers and transferability to other ties. Regarding private information, multiplex relationships allow the availability for the parties of a broader set of non-redundant information sources about each other; each source is a different type of tie. Through this information, the supplier can understand the buyer’s idiosyncratic requirements and customize its offerings to meet the buyer’s specific needs or anticipate requirements. This, of course, creates value for the buyer and avoids transferability to other ties. Therefore, the presence of multiplexity in the focal buyer-supplier tie increases the benefits available to the focal buyer in a context of competition such as the one we are analyzing. This is also confirmed by Tuli et al. (2010), who argued that the association between a change in relationship multiplexity with a customer and a change in costumer performance is more positive when the competition intensity in the customer’s industry increases. We can presume, in fact, that the effect of multiplexity on innovation is more positive when there is competition among buyers since multiplexity is a mechanism to strengthen relationships and protect against opportunism.

(c) *Need to foster positive knowledge leakage*

On the other hand, a voluntary agreement between the focal buyer and the supplier (strong tie) implying joint involvement in product development spurs the flow of information and knowledge from other buyers to the focal buyer through the shared supplier. A co-makership agreement is an organizational style grounded on peer-to-peer cooperation among business partners, and it is an intermediate form between vertical integration and market mechanisms. The strength of the tie is fundamental in this context, where the shared supplier must have a preference to behave in favor of a single buyer and where it is important to adopt a relative perspective to evaluate the advantage of the buyer with respect to the other buyers. In this way, a buyer can benefit from the supplier's information about other buyers and, at the same time, can avoid the risk related to the misappropriation of information.

The weak ties among the supplier and the other buyers allow the occurrence of positive "leakiness" (Bengtsson & Eriksson, 2002): the flow of information outside the single supplier-other buyers relations, through the supplier, as well as the accumulation of broader knowledge on the part of the supplier. Information on the different applications of a given component can flow out of supply relationships. The buyers are an important source of valuable re-deployable knowledge for the supplier. The supplier will also have an increase in competencies because it is important for a supplier to have contacts with which it can try new products and redeploy them. Often, a firm in a component business cannot develop new products on its own but needs a car manufacturer to work with. Nishiguchi (1994) found that suppliers' customers, not their internal R&D units, are the primary source of innovative ideas. Interactions with multiple customers favor innovation in the Schumpeterian view: "it consists to a substantial extent of a recombination of conceptual and physical materials that were previously in existence" (Nelson & Winter, 1982; Shane, 2000). Product innovation is the strategic reworking of an innovation developed in other fields of application, turning a certain technology to satisfy a different customer usage function (Onetti & Lodi, 2004). The novelty of innovations lies in the novel ways in which these elements are recombined (Nooteboom, 2000). In fact, knowledge is imperfectly shared over time and across people, organizations, and industries. Ideas from one group might solve the problems of another.

Clear evidence of this is provided by Hargadon and Sutton (1997), who demonstrated in an ethnography study how a successful product design firm (IDEO) can exploit its network position, bridging structural holes between clients in 40 different industries, increasing its novelty potential. Through abstraction, the supplier acquires creative potential and the ability to implement complex tasks. It acts as a technology broker by introducing existing technological solutions where they are not known and creates new products that are original combinations of existing knowledge.

This means, in our case, that if the supplier has direct ties with many buyers (high centrality), it has greater potential innovation output; however, the competition for information and innovation bars the focal buyer's positive payoff. This, in turn, becomes more advantageous for the buyer if we add the strength element.

(d) *Conclusions*

In the end, the best situation is one in which the focal buyer has a strong tie with a supplier that is central in a network of weak ties. In this case, the combination of positive "stickiness" and positive "leakiness" (Bengtsson & Eriksson, 2002) explained above engenders a positive leverage effect that moderates the main effect shown in hypothesis 3. This is a solution that allows for exclusive solutions developed by the supplier for the focal buyer, ensuring protection from the competition, but allowing also the supplier's knowledge enrichment with other buyers. For the focal buyer, there is only the benefit of innovation creation without the problem of exploitation and patent race.

For completeness, if I consider the other possible value of the ratio (strength in focal buyer-supplier on strength in supplier-other buyers), I find other scenarios. First, there is the case in which the supplier-focal buyer tie is weak and the supplier is involved in many strong ties with other buyers. Second, there is the case in which the average strength of the focal buyer-supplier ties and supplier-other buyers ties is similar. I explain them next.

If the supplier-focal buyer tie is weak and the supplier is simultaneously involved in many strong ties with other buyers, we have the opposite situation with respect to the one described above, and I can presume a negative effect on the focal buyer's innovation. This asymmetric information flow is not favorable for the focal buyer. The supplier is expected to act on behalf of other buyers with which it has strong ties, cooperating with them to get innovations. The collaboration with them in different co-development projects enriches the supplier's knowledge, but these relationships should be characterized by enforcing mechanisms that protect against knowledge spillovers to the focal buyer, which, consequently, is in a bad situation. Also, if we think in terms of multiplexity (the highest level of strengthin my ties), multiplexity in the supplier's external vertical network but not in the supplier-focal buyer tie causes a situation of asymmetry and lack of balance. Therefore, in the case of a weak tie between the focal buyer and the supplier, the centrality of the supplier in a network comprising strong ties (which, in the worst-case, are also multiplex ties) with buyers has a negative effect.

Finally, the strength can be similar both in the focal relation and in the external relations involving the supplier – with either strong or weak ties. This situation seems to engender a neutral effect. Consequently, it will not alter the original main effect of the supplier's centrality on the buyer's innovation output.

The two extreme cases we have analyzed, involving (1) a strong focal buyer-supplier tie and weak buyer-other suppliers ties and (2) a weak focal buyer-supplier tie and strong buyer-other suppliers ties, allows me to formulate the hypothesis focusing on the relative strength between the focal buyer-supplier tie versus the supplier-other buyers ties. The explained line of reasoning leads to the conclusion that a positive effect of the moderation of the relative strength of direct ties linking the buyer to suppliers versus the strength of the ties linking these suppliers to other buyers is expected to act on the main effect presented in hypothesis three. I can, thus, formulate the following hypothesis.

HP 4: ***The impact of supplier's centrality in the network of buyers on buyer's innovation output is moderated by the relative strength of the direct tie between the buyer and the supplier versus the strength of the ties between this supplier and other buyers:***

the higher the relative strength of the direct tie between the buyer and the supplier versus the strength of the ties between this supplier and other buyers, the lower the negative impact of suppliers' centrality in the network of buyers on buyer's innovation output.

3.5 Conclusions

In this chapter, I have shown the theoretical framework resulting from the gaps identified in the literature review (cf. chapter 2) and that I am going to test with the empirical analysis (cf. chapter 4). I have presented the line of reasoning underlying my four hypotheses. In general, the underlying conceptual frame showing how the knowledge flows to the focal buyer involves the elements shown in the figure below. Basically, the focal buyer's payoff results from how information flows to it, how much access to information it has, and how information flows in the external network.

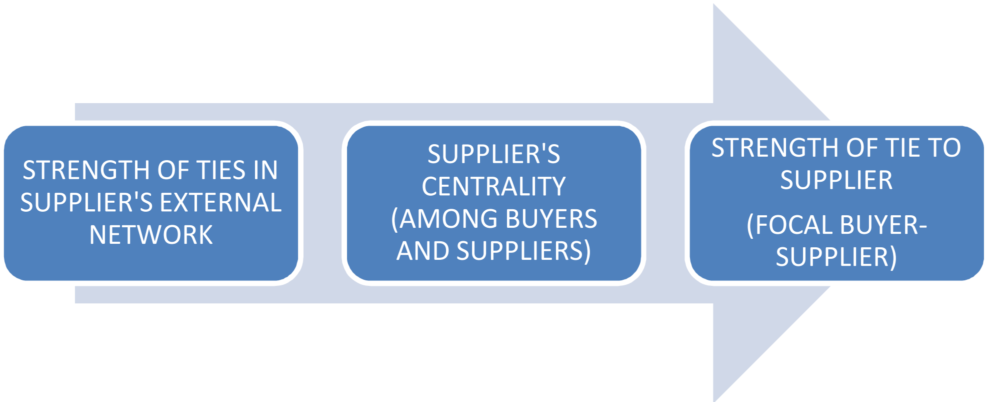


Fig 1.3 Total knowledge flow to the focal buyer

CHAPTER IV - Research Design

This chapter illustrates the empirical work carried out to test the theoretical framework developed in the previous chapter. It includes explanations about the sampling and data collection procedures, the description and operationalization of variables, and the statistical model used. In addition, it describes the empirical setting of the research, the motor-vehicle industry.

The chapter is divided into five sections. The first section presents the formal model that has been used to test the hypotheses. The second section describes the motor-vehicle industry, focusing on the reasons why it is a setting suitable to the present theoretical study. The third section provides details about the sources for sampling and data collection and illustrates the different steps carried out to get the final dataset, which comprises network data, patents data, and financial data. The fourth section presents the descriptions of all variables and measures.

4.1 Model specification

The thesis aims to assess the effect of the supplier's network on the buyer's innovation using quantitative methods adopting social network analysis (SNA) and a regression model. The first one led to the identification of network characteristics and actors' positions through the computation of network variables. After the network analysis, traditional estimations of the effects that network variables have on a firm's innovation have been implemented through a regression model.

The hypotheses developed in chapter three identify one dependent variable: the innovation performance of the focal buyer. Hypotheses one and three predict two main effects of the supplier's centrality among suppliers and among buyers on the buyer's innovation output, while hypotheses two and four introduce the moderating role of the strength of ties.

I specify the equation that ensues from the aforementioned theoretical model. In the equation, the dependent variable, the focal buyer's patent count, is regressed against the vector of explanatory variables including both hypothesized effects and controls. I use a longitudinal research design and therefore all variables are indexed over firms (i) and over time (t). Using a pooled cross-sectional notation, the regression equation can be written as follows.

FB Patents $_{it}$**=**

$$\beta_0 + \beta_1\,(\text{Centrality S1-S2})_{it-1} + \beta_2\,(\text{Tie Strength FB-S1})_{it-1} + \beta_3\,(\text{Centrality S1-S2}) * (\text{Tie Strength FB-S1})_{it-1} + \beta_4\,(\text{Centrality S1-B2})_{it-1} + \beta_5\,(\text{Relative tie strength FB-S1/S1-B2})_{it-1} + \beta_6\,(\text{Centrality S1-B2})*(\text{Relative tie strength FB-S1/S1-B2})_{it-1} + \beta_7\,(\text{controls})_{it-1} + \varepsilon_{it}$$

Specifying the controls it becomes:

FB Patents $_{it}$**=**

$$\beta_0 + \beta_1\,(\text{Centrality S1-S2})_{it-1} + \beta_2\,(\text{Tie Strength FB-S1})_{it-1} + \beta_3\,(\text{Centrality S1-S2}) * (\text{Tie Strength FB-S1})_{it-1} + \beta_4\,(\text{Centrality S1-B2})_{it-1} + \beta_5\,(\text{Relative tie strength FB-S1/S1-B2})_{it-1} + \beta_6\,(\text{Centrality S1-B2})*(\text{Relative tie strength FB-S1/S1-B2})_{it-1} + \beta_7\,(\text{ROA})_{it-1} + \beta_8\,(\text{R\&D intensity})_{it-1} + \beta_9\,(\text{Current ratio})_{it-1} + \beta_{10}(\text{Debt to equity})_{it-1} + \beta_{11}(\text{Emp})_{it-1} + \beta_{12}(\text{Patents S1})_{it-1} + \beta_{13}(\text{Supply ties FB-B})_{it-1} + \beta_{14}(\text{Horizontal ties FB-B})_{it-1} + \beta_{15}(\text{SH efficiency})_{it-1}\beta_{16}(\text{Presample patents})_{it-n} + \varepsilon_{it}$$

where FB = focal buyer, S = suppliers, B = buyers, just motor-vehicle assemblers. Specifically S1 are suppliers located at distance one from the focal buyer, while S2 and B2 are suppliers at distance two and buyers at distance two from the focal buyer respectively.

The four hypotheses are tested looking at the sign and significance of the following variables: Hp1: (Centrality S1-S2); Hp2: (Centrality S1-S2) * (Tie Strength FB-S1); Hp3: (Centrality S1-B2); Hp4: (Centrality S1-B2) * (Relative tie strength FB-S1/S1-B2).

I used a lag of one year between the dependent variable and the regressor values: the dependent variable is computed at time t, while all the regressors are computed at time t-1. The variable Presample patents is the presample computed by cumulating the focal buyer's patents preceding the period under analysis and it is based on a three-year window.

The dependent variable, innovation output, as represented by patent counts, is a count variable and takes only non-negative integer values. The linear regression model assumes homoskedastic normally distributed errors. Because these assumptions are violated with count variables, a count model will be used, either a Poisson or negative binomial regression depending on the presence of overdispersion in the data (standard deviation of data exceeds the mean) (Hausman et al. 1984).

4.2 Empirical setting: the motor-vehicle industry

The choice of the motor-vehicle industry as the empirical setting for the analysis has multiple motivations primarily related to the type of product marketed in it and to the presence of inter-firm networks. First, product development (and therefore also innovation development) ensues from the interaction of different parties. It is basically collaborative in nature because of the product characteristics I will analyze below, in particular the complexity typical of a "fabricated-assembled" product. Second, the motor-vehicle industry is a prominent example of a sector where one encounters inter-firm networks on a large scale. This is manifested by many sources (e.g., Dyer, 1996; Fine & Whitney, 1996). In particular supplier-buyer relationships are of great importance. More in general, the industry has the characteristics of a business system that favors the development of strategic buyer-supplier networks. These are suggested by Chou (2006): (a) an industry with high clockspeed (given by the rate of technological innovation and the extent of competitive intensity) and by Jarillo (1993): (b) at least some critical activities have advantages if carried out in a de-integrated way; (c) specialized investment such as capital investments, people, or time, results in higher efficiency; and (d) speed of responsiveness is important and leaving coordination just to arm’s-length market mechanisms is inefficient.

Moreover, the choice of the motor vehicle industry is valuable in terms of contribution to the network literature. In fact the empirical setting of current network-based studies has remained quite narrow, in spite of claims to generalizability. Institutional contexts where relational explanations are favored (e.g. biotechnology) were preferred by researchers, while relatively fewer studies focus on mature industries characterized by vertically integrated processes of mass production and distribution (Lomi & Pattison, 2006).

After a short definition, I will highlight some industry traits related to my analysis.

As for the definition of the industry, it is comprised of establishments primarily engaged in manufacturing or assembling complete automobiles, trucks, commercial vehicles, and buses, as well as specialty motor vehicles intended for highway use such as ambulances, armored cars, hearses, fire department vehicles, snow plows, and tow trucks. Subcategories included in the industry are: motor vehicles and passenger car bodies, truck and bus bodies, motor-vehicle parts and accessories, truck trailers, and motor homes. This definition corresponds mostly to the Standard Industrial Classification (SIC) category 371, “motor vehicles and equipment” and is the original definition. From 1998 on, the Commerce Department switched to the North American Industry Classification System (NAICS), and it has recalculated industry output on the NAICS basis back to 1987 (Cooney & Yacobucci, 2007). The industry classification is somewhat broader in the NAICS than in SIC 371, because NAICS 3363 incorporates products previously included under non-automotive categories (e.g., automotive air-conditioning equipment). It includes the categories of motor vehicles manufacturing (NAICS 3361), separately produced motor-vehicle bodies (NAICS 3362), and motor-vehicle parts (NAICS 3363); these are commonly combined in the Bureau of Economic Analysis data as “motor vehicles, bodies and trailers, and parts.” However, the SIC and NAICS automotive data are similar enough to be considered alternatives for each other.

The motor-vehicle industry is unique in that it brings together an extremely complex set of components from multiple sources. A motor vehicle is made of approximately 15.000 components[3] per vehicle and from 60 to 80 percent of a vehicle is sourced externally. Mechanical and electronic systems are designed and integrated to meet the preferences of consumers and the requirements of regulators. This huge amount of components must be produced, delivered, and assembled in order to produce a well-functioning vehicle. The buyer of a motor vehicle is buying a product to which several thousand companies have contributed. The motor vehicle is assembled from many different parts that in turn are made of other parts; behind each part lies a chain of refinement starting with a raw material and including different stages of processing in which different companies may have participated. All the parts of the vehicle must fit together and they must be of the right shape and dimension. The production stages must be timed so that people and machinery are available. Hence there is within the system a great need for coordination of all the operations that in many ways are interdependent. Since many of the companies are dependent on other branches of industry for their activities, the need for coordination extends throughout the industry (Forsgren et al., 1995).

In the motor-vehicle industry, product development is becoming crucial for competition because technology is increasingly more complex and diverse. Looking at new technologies, one

[3] The thousands of parts that go into a motor vehicle basically contribute to two main functions: some of the parts help to create the power by which the vehicle is propelled, and some help to create the body that holds the power source, as well as passengers and goods. The body consists of two principal modules: the passenger compartment and the exterior skin. The powertrain consists of three principal modules: chassis, engine, and drivetrain (Rubenstein, 2001).

can see a shift from a traditional V-8 engine with rear-wheel drive of 20 years ago to a variety of engine-drive train combinations today. The same happened in brakes and suspensions, engine control systems, and materials and electronics (Clark & Fujimoto, 1991). Speed, efficiency, and effectiveness in product development become key drivers of competitive advantage.

Product development in this industry has peculiar characteristics derived from the simultaneous complexity of two elements: the *product* and the *process/project* to develop a new product. The complexity of a product can be defined along two dimensions: complexity of internal structure and complexity of user interface. The motor-vehicle product shows high levels of both. The complexity of the process/project is given by the number of different stages it includes, by the number of diverse actors it involves, and by the level of interdependence required among stages and among actors. I will shortly examine the aforementioned aspects.

A vehicle has *internal complexity* because it is a "fabricated-assembled" product with a high number of distinct components and production steps and high interdependence among components that imply internal coordination and technological challenges and sophistication. More specifically, there is a hierarchy of parts, components, systems, and modules. A *part* is typically a small, individual piece, either a standardized generic item such as a bolt, or a piece of metal, rubber, or plastic stamped, cut, or molded into a distinctive shape. A *component* consists of several parts put together into a recognizable feature, such as a seat cover or camshaft. A *system* combines several components to make a functional portion of a motor vehicle, such as an instrument panel or a transaxle. A *module* integrates several systems into one of the major units of a motor vehicle, such as a passenger compartment or engine (Rubenstein, 2001).

The requirements from buyers to suppliers increasingly moved from parts to modules starting in the 1980s with the diffusion of lean production practices. This kind of demand requires higher competencies and combination capacities on the part of the suppliers and the availability of diverse knowledge and a broader perspective and knowledge scope that a supplier can derive from its own network of contacts. In this respect a supplier's network position and resources play a more significant role. Originally, producers assembled thousands of individual parts supplied by thousands of individual companies (e.g., knobs, wires, stamped metals, and gauges were purchased by different suppliers to build instrument panels). Afterwards, an efficiency-driven logic led buyers to ask suppliers to provide components instead of parts (e.g., radios complete with wires and knobs, ready to pop into the instrument panel), then systems instead of components (e.g., entire instrument panels, complete with knobs, gauges, and padding), and finally modules instead of systems (one supplier can be contracted to provide not just instrument panels, but seats, door, headliners, floors—the entire passenger compartment) (Rubenstein, 2001). Finally, to balance low dependence on suppliers and efficiency, the trend in buyers' behavior starting from the twenty-first century has been to satisfy their demand by buying large modules and systems, but still buying some small components and parts at the same time.

A vehicle also has *external complexity*, meaning that it is complex from the buyer's perspective, giving rise to several different performance dimensions. Most of them are subjective, indefinite, subtle, emotional criteria, difficult to translate into technical specifications. The user interface is multifaceted in that a vehicle can satisfy customers in a number of ways beyond basic transportation, not all of which are clearly recognized by the customers themselves. This enhances the importance of the interaction and collaboration between buyers and suppliers because in a context like this the knowledge of users' needs and perceptions is fundamental for product and innovation development. The main conclusion in this respect is that on one hand buyers need to assemble advanced components in an innovative manner to be innovative, and on the other hand suppliers need specifications derived from the users' hints and collected by the buyers to provide up-to-date and adequate components.

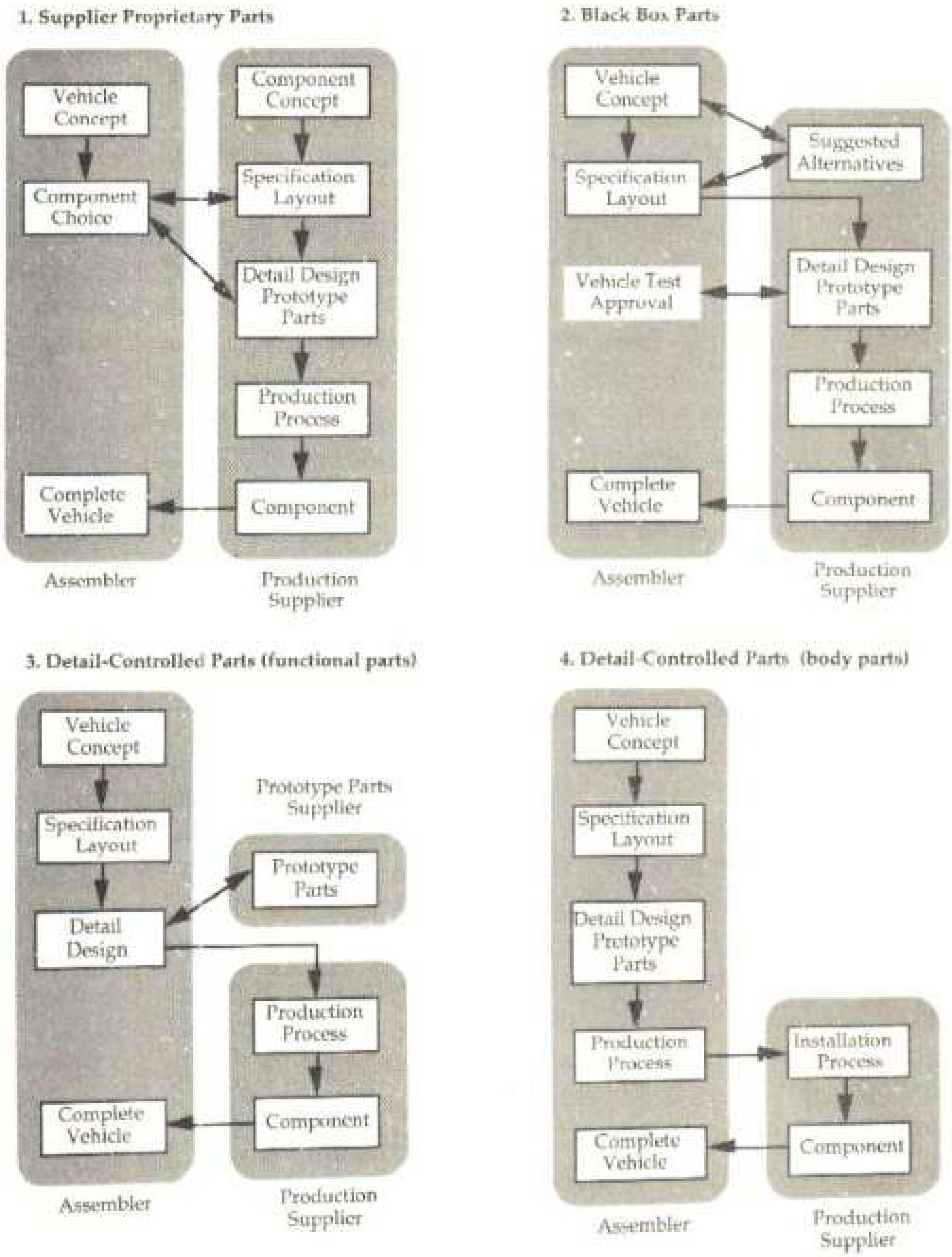
Second, as for the *process/project*, a project to develop a new car is complex and long-lived; it may involve thousands of people for a long time and it is characterized by engineering complexities. Planning and design are complicated by changing markets and long lead times. Although each manufacturer has its own version of a product development process, a standard set of steps is used by all manufacturers to structure product development - *concept, feasibility, design, pilot, ramp-up,* and *commercialization* - that gives an idea of the complexity of the process. Several stages imply greater interaction between suppliers and buyers; the discussion now turns to the way in which this interaction occurs.

Once a *concept* has met approval at a board level, it is translated into "product intent" and technical requirements, which are then reviewed during the *feasibility* stage. The project and manufacturing plan, product criteria, and a full program budget are the output. The *design* stage includes the interaction with suppliers: The creation of a more detailed design based on outputs from the feasibility stage and on inputs from suppliers occurs. Updates are made to the manufacturing plans and supplier plans are finalized. The purchasing function facilitates sourcing decisions (i.e., supplier selection) with inputs from both engineering and manufacturing compartments. Suppliers with characteristics (e.g., quality, cost, design, delivery, and financial performance) that meet the manufacturers' criteria are asked to quote on a vehicle system or component. Depending on the specific program requirements, a varying combination of manufacturer and supplier resources will be brought together to create the system design. Overall systems engineering responsibility resides with the vehicle manufacturer, which facilitates integration of the various components, sub-systems, and systems that combine to create the final product.

Obviously, the concept, feasibility, and design stages of the motor vehicle are a function of the concept, feasibility, and design stages of all its components. Supplier involvement in the design and development of a vehicle can take place in different ways corresponding to different components, as shown in figure 1.4. In the case of *supplier proprietary parts* standard products are taken from concept to manufacturing by the supplier and sold to assemblers through a catalogue. Economies of scale are the advantage. In the presence of *black box parts* development work is shared between the assembler and the supplier; the assembler generates cost/performance requirements, exterior shape, interface details, and other design information based on the total vehicle planning and layout. This is partially risky: basic design and styling ideas can leak to competitors through the supplier. In a *detail controlled parts system*, most of the component engineering work, including parts drawing, is done in-house. Detailed and basic engineering are in the hands of the motor-vehicle maker. Suppliers are in charge of process engineering and production based on blueprints provided by the assembler.

Subsequently, the production readiness of suppliers and tooling is ensured during the pilot stage when the confirmation that vehicle production can meet the volumes that the marketing plans require takes place. Product and process integrity are validated in addition to the completion of the launch plan. Finally, supply chain issues are resolved and tracking plans finalized for production criteria during the *ramp-up* stage. Product performance is confirmed with regards to cost, quality, and delivery and the program transitions into the *commercialization* stage.

In general, the decision concerning the amount of development that must be conducted using the manufacturer’s internal resources or using suppliers is increasingly complex. There are several reasons for manufacturers to rely on supplier collaboration. First, as vehicle complexity (e.g., electronics) has increased, it has become extremely difficult for a manufacturer to maintain the necessary competencies to design, develop, and manufacture many systems, thereby creating the need to look outside. Second, supplier capabilities have increased significantly in recent times.



Main information asset created

Main information flows

Fig. 1.4. Typical information flows with parts suppliers (Clark & Fujimoto, 1991).

Therefore, suppliers continue to enhance their innovation efforts and share of vehicle development such that three-quarters of the cost of a vehicle is coming from suppliers[4]. As a consequence the effectiveness of the purchasing function has a larger bearing on a manufacturer's performance. In parallel with supporting individual programs, the purchasing function is also tasked with developing its supply base. With such a high proportion of a manufacturer's costs residing with suppliers, it is critical for purchasing to ensure that suppliers deliver the right products, at the right price, at the right time. This is becoming crucial for manufacturers to achieve, as the source for both innovation and developments migrates to suppliers.

Looking at the real strategies carried out by the motor-vehicle companies in previous decades, one can see that before 1920 suppliers often participated in component design and their innovations proved instrumental in creating viable vehicle designs. As the 20th century progressed and North American manufacturers increased their internal parts design and production capabilities through vertical integration, the need for suppliers with design capabilities declined significantly. The Japanese influx of the late 1970s and early 1980s brought increased competition, technology changes, and foundations for a new sourcing model for American companies. Originally the Japanese and the American models differed in that in the first supplier-buyer relations have always been mainly collaborative, while in the second they were adversarial. About the turn of the 21st century in the American context companies spun off their internal parts divisions and, in doing so, increased the need for their new suppliers to raise their design and innovation capabilities. Subsequently increasing pressure has been placed on profitability. In an effort to address such issues, companies have turned to their supply base to reduce costs, increase innovation, and share warranty.

In general the quality of the relationships between North American manufacturers and the suppliers is not as collaborative as in the case of the Japanese manufacturers. The tensions that might exist between suppliers and manufacturers stem from many potential sources. One source is certainly the context of increasing global competition and reduction in market share. This has forced manufacturers to attempt to control costs at every opportunity and innovate where possible in an attempt to increase product attractiveness. They increasingly look to their supply base for relief. Often they opt to shop a supplier's intellectual property, "market test" suppliers' prices, and

[4] Supplier's share of vehicle development is expected to increase from 37 percent in 2002 to 63 percent in 2015 (McKinsey and Company, Inc., 2003).

demand concessions from suppliers. Through various means, suppliers have voiced their objections to the methods used by manufacturers with regards to pricing, intellectual property, and warranty. According to suppliers manufacturers that adopt such actions clearly reflect a short-term mentality.

Particularly with respect to intellectual property some issues exist. Suppliers traditionally work on a design but do not receive payment for their contributions until production starts. A supplier will invest for the length of the development program and typical not receive any payments for the development work from the manufacturer during that period. The supplier will amortize any investments into the price of the parts, recovering costs over the life of the production program. This creates the conditions for opportunistic behavior of the buyer. Some manufacturers create a second competitive bid once a supplier has created the drawings, so that they can squeeze further on price or get further innovative advantages. The supplier that creates the design and makes the initial investment is disadvantaged as it has a cost wasted and an idea disclosed that other bidders do not have. As one supplier states: "American automakers have us work on drawings, ask other suppliers to bid on them, and give the job to the lowest bidder" (Liker & Choi, 2004). Some manufacturers demand that suppliers contractually waive their rights to such intellectual property (unless patented) and will shop the technology at the first opportunity.

On the other hand, the supplier's power is explained well in the words of Nick Scheele, formerly president of Ford: "unhappy suppliers might dedicate their best people, invest their best resources and offer their newest technology and innovation to our competitors, putting Ford at a competitive disadvantage" (Chew & Whitbread, 2002). In this respect, a supplier executive said: "If we are squeezed on price it is less likely that we will offer new technology to that customer as we will not get return on that investment" and "some manufacturers will find themselves cast-off the leading edge of technologies and supplies" (Chew & Whitbread, 2002).

To conclude, the world motor-vehicle industry is a microcosm of the new industrial competition. The rivalry among motor-vehicle manufacturers is extremely intense. Each segment of the market is highly competitive with manufacturers increasing the frequency at which they renew the products they offer. The competitive pressures in today's industry exacerbate the need for successful decision-making processes that help in defining the products and the respective attributes to be engineered into a vehicle, and the resources needed to create and manufacture products. Motor-vehicle companies continuously trade off the pros and cons of conducting product design, development, and production internally versus purchasing such activities from suppliers. Innovation, effectively applied, can solve problems related to cost, regulation, and consumer needs, and is a prerequisite for competitive products across most segments of the motor-vehicle market.

The last remark I want to point out regards the external validity of the study, meaning the applicability of the same predictions and mechanisms to other industries. Many of the critical problems in developing a new motor vehicle - integrating engineering and manufacturing, establishing links between technical choices and customer requirements - show up in the development of most "fabricated-assembled" products. Even in process-intensive industries such as steel, aluminum, and engineered plastics these problems are sufficiently general that analysis of the motor-vehicle industry can provide useful insights.

4.3 Sample and Data collection

This section of the chapter reviews all the steps that led to the achievement of the final dataset employed to implement the statistical model and test the hypotheses. The building of the dataset was perhaps the main effort of the work, involving a huge amount of time and attention. This was also due to the high number of firms included in the sample, mainly related to the method of analysis. In fact, network approaches tend to study populations by means of a census. Since network methods focus on relations among actors, if one actor is selected then all other actors to whom that actor has ties must be included according to the criteria chosen.

The overall process started with the sampling procedure, consisting of data collection, execution of cleaning procedures, and final identification of the firms in the sample. Subsequently collection and elaboration activities were implemented in three principal fields: relational data through network analysis, patent data, and financial data. I elaborate on each of these in the following subsections. All the data collected have been elaborated, matched, and exploited through extensive use of Microsoft Access.

4.3.1 The sample: data collection and identification of the nodes

The empirical study is focused on the U.S. motor-vehicle industry. The sample includes all the suppliers operating in the United States and their customers, which are motor-vehicle companies and other suppliers. To obtain the final sample the following procedure was followed.

First a list of all the suppliers established in the United States was drawn up using as a main source the directory *ELM Guide of US Automotive Sourcing.* The *ELM Guide* is a reliable source that is acknowledged in the industry and that has been already used in the literature by several authors (e.g., Chung, Mitchell, & Yeung, 2003; De Jong & Nooteboom, 2001; Martin, Mitchell & Swaminathan, 1995; Delmas & Montiel, 2009; Helper, 1994; Henke, Parameswaran & Pisharodi, 2008; Klier, 1998, 2000; Klier & McMillen, 2006; Mudambi & Helper, 1998; Okamoto, 1999; Sako & Helper, 1998; Sako, Lamming, & Helper, 1994; Wu, 2003). However, its use in a wide network context is a somewhat new application. The trustworthiness of the source of data merits attention. The *ELM Guide* is the result of a survey carried out periodically. As Klier (1998) asserts, it is difficult to accurately assess the coverage of this directory, since the size of the true survey population is unknown. However, anecdotal evidence on Honda (Mair, 1994) and Nissan (Bennet, 1994) indicates good coverage of the tier one supplier plants. Moreover, the information obtained from the *ELM Guide* is qualitatively consistent with previously published accounts (Mair et al., 1988; Kenney & Florida, 1992; Rubenstein, 1992; Mair 1994). Hence systematic bias in the results is unlikely.

I retrieved suppliers' lists for five years: 1994, 1996, 1998, 2001, 2004, corresponding to the years of publication of the *ELM Guide* volumes, since they are not published yearly. The printed version of the data was transposed into an electronic database. Total number of suppliers identified was 1,203 suppliers in 1994, 1,330 in 1996, 1,245 in 1998, 1,209 in 2001, and 1,156 in 2004. I collected data at the company level (the *ELM Guide* includes data at both the plant and company level). Companies that produce machine tools or raw materials and those that produce primarily for the aftermarket are not part of the ELM database. The data include information on “captive” suppliers that assemblers own and operate themselves, such as engine and stamping facilities.

Besides the sampling process, through these volumes I obtained additional information for each company, such as parent company names, ownership (public, private, or joint venture), location with ZIP code, date of establishment, number of employees, sales figures, number of plants, parts, processes, raw materials, and countries in which they export. These data are expressed at the company level, meaning typically the subsidiary level. They can be exploited for further development of the research and investigations at the subsidiary level. On the contrary, for the purposes of this thesis, the study is executed at the corporate level of analysis, focusing on the ultimate parent companies of the subsidiaries listed in the *ELM Guide*. Therefore, the information useful for the current empirical work includes parent company name and ownership. However, to make sure that they were correct, and also that the parent company mentioned from the supplier was the ultimate parent and not an intermediate parent company, I conducted a search in other sources, more focused and specialized in providing that kind of information (*Who Owns Whom: Directory of Corporate Affiliations* volumes by Dun and Bradstreet and the *Corporate Affiliations* database by LexisNexis). The principle underlying this choice is to use the most suitable data source for each specific type of data and to use, whenever possible, multiple comparable sources.

The second stage of the process to get the final sample consisted of the identification of the ultimate parent company, for each supplier under analysis, for each of the five years. I carried out this activity using two complementary sources: *Who Owns Whom: Directory of Corporate Affiliations* volumes by Dun and Bradstreet and the *Corporate Affiliations* database by LexisNexis. These sources report the corporate hierarchy of the companies over time, listing all the subsidiaries of a given parent company. The first one consists of printed volumes by year and geographic region. The second one is an electronic database that in the historical search section comprises data from 1993 to 2010. I supplemented these sources with the NBER files that, for the North American public companies, report the match between all the patent assignees (including subsidiaries) and their parent companies found in Compustat North America. I will explain later the specific structure of these files, in the patent section. These files, particularly the one named "dynass", match patent assignees' standard names to the parent companies dynamically, recording each parent with the related period of ownership to take into account change in corporate ownership. Matching the firms in the sample with the standard names of the patent assignees I was able to use the match provided in the files to get the corresponding Compustat parent company, as an additional source.

By recording the parent companies in the different periods found through the aforementioned sources, I also recorded changes in the ownership structure of the companies and different subsequent parent companies for the same supplier over time. To check for these cases I integrated the aforementioned data sources with the *Merger Track* section of LexisNexis. The cases of mergers were also isolated and taken into account. Moreover, I searched newspapers and online libraries for information about ownership changes regarding those firms that did not appear in any of the aforementioned sources. Another additional source was the electronic database, One Source, which reports the current corporate hierarchies of firms. In the ownership section of the *ELM Guide* some companies were identified as JV (joint ventures) between two companies. For these cases I searched for the parent company of each of the participating companies and I included it in the sample.

The third step for the identification of the nodes consisted of the coding of the corporate entities identified. The coding obviously passed through a preliminary activity of standardization of names. Dealing with the difference in the spelling of the same name in different sources or even in the same source over time was the first hindrance to overcome. Beyond the spelling issue it was important to find all the cases in which a change in the company name occurred. In these cases the same unique identifier of the company (assigned code) had to be assigned to the multiple names. This name changes could occur at the subsidiary and at the parent level, both of which were verified. A subsidiary's name change was mainly discovered through the *ELM Guide* from the presence of the same data for two entries over time (i.e., in two subsequent years) differing just in the company names. A parent name change was identified mainly in two ways. First, by checking *Corporate Affiliations* by LexisNexis, which records the different parent names over time. Second, by checking one by one for all the cases in which a subsidiary changed parent company during the five years under analysis. In this way it was possible to distinguish whether the new parent company was the result of an acquisition, a merger, or a simple name change. The identification of a change in the parent company was made possible through the prior coding of the subsidiaries which had led to a matching of individual subsidiaries to parents. In the end, the coding included a code for the parent company that differed depending on the category (namely supplier, motor-vehicle company, customer-supplier), and two codes for the subsidiaries, one independent from the parent company and one placing the subsidiary under a given parent company.

This above procedure was followed for all the firms considered: (i) suppliers in the original ELM list (original equipment manufacturers, [OEMs]), and (ii) customers that are in turn divided in two categories: (a) customers that are motor-vehicle companies, namely assemblers, and (b) customers that are other suppliers. A different type of code was assigned to each of the three categories to keep them clearly recognizable in the various data elaboration activities. Naturally, some of the suppliers listed as customers can be also included as suppliers in the original ELM list; in that case they will have the same code. For the purposes of this study no distinction is made in the formulation of the hypotheses between tier-one and tier-two suppliers or other tiers' suppliers. However, the *ELM Guide* includes suppliers of different tiers. I have recorded this distinction in the attributes of the nodes in the network, classifying as tier-one the suppliers selling parts just to motor-vehicle manufacturers, as tier-two the suppliers providing components just to other suppliers, and as mixed tier the occurrence of both cases simultaneously. This is something that can be used for further development of the research.

The fourth step included the exclusion from the sample of some of the corporate entities identified through the *ELM Guide* and the aforementioned steps and sources. Specifically, among the customers, I excluded from the assemblers those entities not operating in the motor-vehicle industry and from the suppliers the aftermarket businesses. These two types of nodes are beyond the scope of the present study. Finally, I was forced to exclude a few suppliers that did not provide the list of their customers. To keep them inside the sample and consequently inside the network would have been a distortion in that they would have been included as having zero ties when there was instead just missing data. They did not have zero customers, they just have not disclosed their customers.

Even though the sample is made of about a thousand entities yearly, which form the network to implement the network analysis and to compute network variables, the dependent variable in the regression model refers to the motor-vehicle companies. The number of these companies is small in the industry and the sample comprises 58 motor-vehicle companies included in all or in some of the years of the study. I analyzed the differences in the sample composition among years as for motor-vehicle companies to check for the existence of a reason for the presence of a motor-vehicle company in some years and not in the others, such us acquisitions, mergers, or termination. All the cases fell in one of these categories.

Moreover, I executed two alternative models that differ in the sample composition of the motor-vehicle assemblers and that function as a robustness check. In one case I used the whole sample resulting from the aforementioned procedure; in the other case I identified and excluded from the sample, and consequently from the network, motor-vehicle companies having no operating activities in the United States. This was for at least two reasons, both aiming to avoid the inference of an incorrect causal relationship between the supplier's network characteristics and the buyer's innovation through the introduction of a bias in the model. First, the U.S. suppliers could not be sufficiently representative of the overall supplier base of a motor-vehicle company that is not operating in the United States at all. Hence, recognizing the U.S. suppliers' network as an antecedent to its innovative output can be too strong an assumption. Second, this study is investigating social exchanges and it could be more difficult to justify or presume the occurrence of a social exchange in the presence of a substantial distance between a supplier and a buyer. It is more likely the presence of a supply tie without much information exchange. I used these two alternative samples to make sure that the results are not altered by spurious effects. I will present the results of the models in chapter five; the findings are that they maintain essentially the same pattern of coefficients and significance. In the end the whole sample is made of 1,096 nodes in 1994, 1,185 nodes in 1996, 1,128 in 1998, 1,060 nodes in 2001, and 1,016 nodes in 2004. In the second model excluding the motor-vehicle companies not operating in United States the sample includes 1,089 nodes in 1994, 1,177 nodes in 1996, 1,120 nodes in 1998, 1,052 nodes in 2001, and 1,007 nodes in 2004.

As a prerequisite to facilitate the subsequent data collection activities, another activity was carried out: the partition of companies into private and public companies year by year. In fact, patent data and financial data collection involve different opportunities and procedures in the case of public or private companies. I draw this information from the *ELM Guide*, LexisNexis, and the Compustat North America and Compustat Global lists of companies accessed through the Wharton Research Data Services (WRDS) web site. I identified around 380 public companies considering the years as a whole; for these companies I recorded identification codes, such as *cusip* or *gvkey*, that were useful then for linking the different sections of the dataset.

4.3.2 The relational data and the building of the network

As already explained, the analysis focuses on supplier-buyer networks; it starts from the assumption that a supplier-buyer network is an interesting field of study in that supply ties and other types of ties are intrinsically mixed in it. Therefore vertical and horizontal relations, namely supply ties and alliances, are simultaneously present and can be added up in a single tie. I summarized the different types of ties in a continuous measure that is the strength of the tie, assigning a specific value to each type of tie. Even though I used an aggregated tool of analysis, the two networks had to be built separately and subsequently merged. I briefly explain the process executed to get the supply ties and the alliance ties.

Supply ties have been obtained, as already mentioned, from the *ELM Guide*, which provides for each year for each supplier a section including its customers: all the buyers listed in the survey by the supplier. This information allowed construction of the five supply networks, one for each of the five years, through the following process. First, I collected data on the supplier-customer ties from the volumes. These data are expressed at the subsidiary level both for the supplier and the customer. Second, since in a previous step I identified the parent companies of all the firms, I executed a match between the original parties involved in a tie (subsidiaries) and the list that associates each subsidiary with its parent company, to transpose the original ties into ties expressed at the parent level. Third, I excluded the few ties listed from the suppliers as tier-two relations with a buyer (i.e., the supplier declared it was a tier-two supplier to a given buyer) without specifying the intermediate direct node of connection because I could not establish the direct relations in these cases. Finally, I uploaded nodes, relations, and attributes - namely, whether the node is a motor-vehicle company or not (for the purposes of the current hypotheses) - into UCINET VI and I was able to build the supply network for each year.

In the network, the ties have been considered as symmetric (even if they are supply ties with a clear direction where one party supplies the other one) because the subject of interest is the social interaction of people connecting with people. This is also in line with the following remark. These supplier-customer ties can involve as customers both another supplier and a motor-vehicle company. I specify that in the development of the hypotheses and also in the regression model the buyer is intended to be understood as the motor-vehicle company, the final product assembler. This is because the value added in a social exchange is given mainly by the nature of the nodes involved in a relation. The suppliers, even if of different tiers, can be considered approximately equivalent in terms of knowledge base. The fact that the supplier is buying a component from another supplier is not enough to classify the supplier in the buyer category when studying the supplier-buyer relations in the motor-vehicle industry, even more because the ties are considered as symmetric because of the interest in the social exchange. If the relations are considered to be symmetric that does not look at the direction of the flow, therefore it is not the direction of the relation that can assign a role to the parties of the relation (e.g., supplier 1 is supplying supplier 2 that consequently is classified as a buyer); this role is given by the inherent nature of the nodes.

Alliance ties have been found using the *SDC Platinum* database, provided by Thomson Reuters, specifically the *Joint Venture/Strategic Alliances* section. This database provides substantial archival information on inter-firm agreements and it currently represents one of the most comprehensive sources of information on alliances (Li et al., 2010). A careful review of the coverage of SDC reveals that the data are widely diversified with different firm sizes and types (public, private, and subsidiary) and that they include both two and multimember alliances (Aydogan & Chen, 2008). *SDC* (Securities Data Corporation) *Platinum* obtains information from publicly available sources such as company announcements, Securities and Exchange Commission (SEC) filings and their international counterparts, trade publications, and news and wire sources. SDC collects the alliance formation announcements and updates the alliance status daily. This is a database widely used in alliance research (e.g., Kale et al., 2002; Chang, 2004; Anand & Khanna, 2000; Sampson, 2004; Oxley & Sampson, 2004; Reuer & Ragozzino, 2006; Sampson, 2007). Anand and Khanna (2000) noticed that the SDC alliance information is reliable and consistent with other sources. For instance, they found that SDC's alliance SIC codes are consistent with the LexisNexis database. Although there have been some concerns about SDC's accuracy of announcement dates, through different sources they verified that in most cases the discrepancy is within a few days, or at most one or two months. As reported in Anand and Khanna (2000) the data go back to 1986; however data prior to 1990 is not equally comprehensive, since SDC initiated systematic data collection procedures for tracking such deals only in 1989. The sample for the current study runs from 1994 to 2004, hence there is no such a problem. In this dataset each data point is an inter-firm agreement. The dataset provides comprehensive alliance details, more specifically, information on the participating firms in an inter-firm agreement, the date of the agreement, the alliance activities, the industry, the status, and the type of agreement. The type of agreement is directly available as binary variables in the *SDC Platinum* database.

For each of the companies in the sample, all the alliances in the period under analysis have been found in *SDC Platinum.* The steps to get the alliance ties were the following. First, to retrieve the alliances of a given firm a way to unequivocally identify the firm was needed. In SDC each name is associated to a CUSIP. For the public companies listed in North America, I was able to upload the already identified CUSIP inside SDC and get the corresponding alliances. For the private companies and for the public companies listed globally (which do not have a CUSIP in Compustat) I needed to conduct a search for them by name, one by one, in the SDC system to find the correct entity and to record the CUSIP assigned by SDC. There were about 1,500 companies. Second, I queried the system to extract all the alliances associated with those codes, selecting as criteria both "Participant Cusip" and "Participant Ultimate Parent Cusip" to make sure that all the alliances of the ultimate parent company as well as those of its subsidiaries were included in the output; this yielded an Excel spreadsheet with all the ties. Third, since the focus is on the impact of the ties on a firm's innovative performance, the output was filtered to keep just the alliances of selected types, namely R&D agreements, manufacturing agreements, supply agreements, and licensing and cross-licensing agreements. Also, I applied a filter to select just certain status details of the agreement, namely completed/signed or renegotiated (thus excluding letter of intent, pending, etc.). Fourth, as for the date of the alliance, a "date announced" and a "date effective" are provided. I always utilized the effective date unless it was missing. Alliances were collected that were effective between 1994 and 2004. Alliances typically last for more than one year, but alliance termination dates are rarely reported. This requires the researcher to make an assumption about alliance duration. Since the choice of a fixed window of some years (e.g., Gulati and Gargiulo, 1999; Stuart, 2000) seems to be equally arbitrary, I used the assumption that the alliance lasts from the date of establishment through the last year of the period analyzed (Gulati, 1995).

Moreover, of course each firm can have alliances with a variety of actors, spanning the boundaries of the industry. Only those alliances aimed at developing innovations potentially useful to the motor-vehicle industry were of interest. However, this does not provide any hint about the SIC code of the alliance; that is the sole parameter in the SDC output that could be used to select the alliances in a specific field. This is because the suppliers of components, and therefore the potential applications of the alliances involving them, fall within a wide range of SIC codes, different from the strict motor-vehicle industry and difficult to identify and circumscribe. As already stated, the ELM directory is a comprehensive list of the U.S. suppliers and the customers that are assemblers cover almost all the motor-vehicle companies. Therefore I matched all the actors involved in the alliances found in SDC with the nodes of the sample; then I selected the alliances involving at least two nodes of the sample, the supply network, in the year under analysis. In this way the knowledge developed in an alliance is very likely to contribute to further development and innovation in the motor-vehicle industry in a more or less direct way. This also solved the issue of choosing the alliances just on the basis of the alliance activities (provided by SDC in the "application text" and "deal text"); even though executed, this activity, was often challenging due to the presence of technicalities that were not always thoroughly understandable. At this point, I was able to build the five alliance networks, one for each year. The alliances found are respectively for the total sample and the sample focused in motor-vehicle companies operating in the United States: 96 and 94 in 1994, 217 and 215 in 1996, 286 and 282 in 1998, 321 and 318 in 2001, and 334 and 330 in 2004.

Finally, I superimposed the two networks - supply network and alliance network - to create a sole multiplex network to conduct the subsequent analysis and compute the network variables. First, I transformed the two matrices representing the two networks into matrices of the same size. Then I joined the two networks to create a multiplex network through the UCINET VI program command: *data => join; transform => multiplex.* The resulting network is a valued network assigning a different value for each kind of relationship (e.g., 1 = supply tie, 2 = alliance, 3 = alliance + supply tie). Subsequently I dichotomized the resulting network to have a network reporting a tie if there were at least one kind of relationship (asking for a 1 in the matrix for values >=1). In this way each cell of the matrix has been covered by the *Kij* indicator, which represents the relationship between actor j and i and is equal to "1" if there is at least one kind of the three aforementioned relationships, "0" if there is not. The subsequent step was the computation of the network variables. The network analysis is focused on the ego-networks of the motor-vehicle companies. At the same time, an effort was made to obtain data on the firms in the network, both patent data and financial data.

4.3.3 Patent data collection

Patents data have been collected from the U.S. Patent and Trademark Office (USPTO) using the National Bureau of Economic Research (NBER) files. I used this source also for firms headquartered outside the United States to allow consistency, as each national patenting system has different rules and standards for application and granting (Griliches, 1990) that could have introduced a bias. Also, the U.S. market can be considered the leading market for patenting and patent competition and the USPTO database has the advantage of being the prime indicator of new technological inventions, and therefore the most relevant one for innovation policies (Narin &

Olivastro, 1988; Jaffe & Trajtenberg, 2002). Furthermore, as Ahuja (2000) pointed out, prior research using patent data on international samples has followed a similar strategy of using U.S. patent data for international firms (e.g., Stuart and Podolny, 1996; Stuart,1998) and statistics from the USTPO (in 1994) indicated that almost half of all U.S. patents were issued to foreign entities.

I collected patent data for the years 1990-2005. The first years were used to compute the pre-sample variable. The last year enabled to apply a lag between alliance network structure and patent output. I obtained patent counts for each firm through the following procedure. First, I matched the names of the parent companies in the sample and of all the subsidiaries of each of them with the patent assignees (using a slightly different procedure between North American public companies, public companies listed globally, and private companies, due to different source availability). Second, I got all the patent data for the assignees identified, using the NBER files. Third, I filtered patent data according to specific needs, namely the years of interest and the technological classes chosen. Fourth, I computed each firm's patent count for each year following two methods functioning as a robustness check: in the first method I assigned 1.0 and in the second I assigned 0.5 to the patents in the presence of co-patenting (i.e., patents issued jointly to the firm with some other firm). I briefly elaborate on each of these points.

The identification of all the patent assignees referring to the firms of the sample followed these steps. For the public North American companies, I used NBER files that include the match[5] between Compustat firms and patent assignees names and other sources used for the other firms (*Corporate Affiliation* and *Who Owns Whom* plus the implementation of a word-matching procedure). I will explain the latter later. I focus here on the NBER files. The NBER files consist primarily of four parts that in all create a link between a Compustat name and all the patent

[5] This matching between assignee names and firms consisted of a multi-step procedure. Assignee names are listed in the patent data from the USTPO, but they are not standardized because of different spellings, misspellings, abbreviations, etc. Using extensive name standardization and matching routines, NBER files grouped these into a single "assignee" that was assigned to a unique number, the "pdpass." Then assignee names were matched to firms and subsidiaries identified in *Who Owns Whom.* This step used an automatic name-matching routine including cleaning and standardization of names. Designators of corporate form (e.g., "Inc.") were removed and common abbreviations standardized. As a result, in a large number of cases the standardized assignee name exactly matched a standardized organization name. Then a word frequency algorithm was used to identify likely matches. Potential matches that included unusual words in both the assignee name and the organization name received high scores and were examined manually. In order to create a correspondence between the standardized organizations found and to uniquely identify organizations present in Compustat, NBER files introduced a variable named "pdpco." Then to track the change in corporate ownership over time, data on mergers and acquisitions of public companies reported in the SDC database were used and the results were reported in the file "dynass."

assignees' names under this company and consequently between a Compustat name and all the patents data that refer to it. The "assignee" file systematizes all the patent assignee names with standard names and assigns to each standard name a code, named "pdpass". The "pdpcodhr" file assigns to each Compustat North American firm name a code, named "pdpco". The "dynass" file establishes the link between the two mentioned files through the codes "pdpass" and "pdpco". Specifically it links patent assignee standard names to Compustat North America firm names, tracing back the subsidiaries to their parent companies dynamically (recording subsequent parent companies in different periods in case of change in ownership). In all, the files assign to a given company the patents of all the subsidiaries over time. Therefore using these files together combined and elaborated through Microsoft Access, I was able to associate the public North American firms (Compustat North America firm names) of the sample to their subsidiaries, namely patent assignees names and codes, pdpass. For the non-matched firms and for each of the public companies globally listed, I prepared a list of all the divisions and subsidiaries for each of the years under analysis using *Who Owns Whom* by Dun and Bradstreet (several countries' editions) and *Corporate Affiliations* by LexisNexis as a prerequisite to collect all the patents under a given parent company. For the private companies, due to the high number of these firms (about a thousand), the list of parent companies and of the subsidiaries present in the *ELM Guide* was prepared. Afterwards, for non-matched firms, for public companies listed globally, and for private companies, I executed a word-matching procedure[6] to match the subsidiary names found with the assignees' names. It was possible to specify the desired percentage of similarity between the words[7] and this yielded the list of the patent assignees corresponding to parent companies.

As for the collection of patent data for the assignees identified, I utilized the NBER file named "Pat_76_06_assg"; it records all the patents and includes all the patent data associated with each "pdpass". For each patent, information such as the dates on which the patent was applied for and granted, the identification number of the patent, the technological category, class and subclass, etc. is provided. Using the list of the "pdpass" corresponding to the sample and matching them with the "pdpass" inside the NBER file, I was consequently able to extract all the patent data, one per line in a spreadsheet. Also, I checked that the application year of the patents of a given assignee was always included in the time range in which that assignee was under the parent in the

[6]The tool employed for the data match is a search engine by Thorsten Doherr.

[7]I fixed the percentage of similarity at 90 percent.

sample. Merging the results on the patents from all the sections (public North America, public listed globally, and private) yielded patents different from zero for 785 distinct firms (across the different years of the study).

Subsequently I filtered the patent data to meet specific needs, specifically for the years of interest and for the technological classes chosen. The first implied just a filter on the application date. The latter deserves an explanation. I filtered the obtained results to keep just the most appropriate technological classes. Some firms in the sample can be diversified firms with lines of business outside the motor-vehicle industry. Their technological efforts are thus also diversified, including patents granted in multiple business areas. For the purposes of this analysis I needed to identify their automotive-related patents. Finding business-specific patents for large diversified corporations is a common empirical problem in research related to patents. To accomplish this identification for the firms in this sample I identified all the patents for the firms in the sample, as explained above. I then computed the frequency distribution of patents across classes for this sample of patents. I then ranked the classes by the number of firms in the sample that had patents in the specific class. Thus, the highest-ranked class by this criterion was the class that had the largest number of firms patenting in it. The logic for this was that if most of the sample firms are patenting in a class such a class would naturally be relevant for motor-vehicle firms. I identified 120 classes that accounted for about 68% of the patents of the firms and included the patenting efforts of 687 of the 785 firms in the sample; and used these classes to conduct the patent analysis. I then examined the distribution for natural "cut-points."

To summarize, the cut-point is not arbitrary but relies on at least three motivations. Firstly, these classes stand for about 68 percent of all the patents in the sample (I computed the cumulative percent value of the frequency). Secondly, I computed another relevant indicator: the number of *distinct* firms of the sample patenting in these classes. They are 687 firms, accounting for about 87 percent of the sample. Thirdly, I carried out a sensitivity analysis, considering different potential levels of top classes; and I found that beyond this threshold the marginal rate of increase in the percentage of patents covered does not increase. For instance, the top 100 classes included 60 percent of all the patents; the top 150 include 75 percent of all the patents. Going from 100 classes to 120 yields a spread of 8 percent, while going from 120 to 150 yields a spread of 7 percent. Finally, I also considered an alternative method: to keep just the classes that were ranked highest both in terms of number of firms and number of patents and delete the others. However, looking also at the content and description of the patents, it turned out that there are classes with a high number of firms patenting in them but with a low number of patents in them that are strictly related to the core automotive industry. This phenomenon is due to the specificity of knowledge and to the different degrees of potential innovativeness in a given field. This outcome shows the usefulness of keeping the high number of firms in the class as the principal driver for the choice.

Finally, as for the computation of the patent count for each firm and year, I followed two alternative methods with regard to the co-patenting issue. I measured the variable in both ways and I executed the regression models in both ways. I identified the patent codes that were attributed to more than one firm; and I assigned for these patents a score of 1 and a score of 0.5 alternatively to each firm. I added these up, obtaining two different count measures. To apply a count model, as required by the type of dependent variable, in the second case I rounded the patent count off to the next integer. In this way, in the first case the firm was assigned all patents issued to the firm; in the second case the firm was assigned all patents issued solely to the firm and half of the patents issued jointly to the firm with some other firm.

4.3.4 Financial data collection

The main sources I used to collect financial data are Compustat North America and Global and Worldscope, two widely acknowledged and reliable tools. I retrieved data through the companies “gvkey” list in the first case and through company names in the second one. I looked through other datasets such as OneSource, Orbis, and Mergent Online but their use was reduced to preserve consistency among the data of different companies.

Afterwards, I adjusted the data for inflation using the Producer Price Index. Then, since the data were originally expressed in each country’s currency, I converted values to U.S. dollars using the archival exchange rates contained in the Compustat Global currency translation information.

When financial data were not available for some years (e.g., R&D expenditures), I used a regression imputation procedure (Little & Rubin, 1987) to impute missing values for the missing variable and complete the data. When it led to negative or improbable values, I attributed the last available data. I retrieved data on all the public companies, both suppliers and motor-vehicle companies, even though for the purposes of the present work, I utilized data on the motor-vehicle companies only. In the end, I excluded the motor-vehicle companies for which it was impossible to find financial information in any of the years under analysis. The final dataset for the regression included 181 observations in the case of the whole network and 156 observations in the network without motor-vehicle companies not operating in the United States.

4.4 Variables and Measures

4.4.1 Dependent variable

The dependent variable is the *focal buyer's innovation output* (*FB Patents* $_{it}$). It is measured through the *patents count*, the number of successful patent applications or patents granted for a firm *i* in a given year *t*. The literature provides good reasons to use this measure as well as inherent limitations.

As Schilling and Phelps (2007) pointed out, one way in which knowledge creation is exemplified is in the form of inventions (Schmookler, 1966). Knowledge embedded in artifacts such as inventions represents the "empirical knowledge" of organizations (Hargadon & Fanelli, 2002). Trajtenberg (1987) concluded that patents are valid and robust indicators of knowledge creation. Patents provide a measure of novel inventions that is externally validated through the patent examination (Schilling & Phelps, 2007). I draw upon an extensive body of research that uses patents as measures of innovative output and regards them as entities with economic significance, conferring property right on the assignee (Ahuja, 2000) and as useful statistics for measuring economically valuable knowledge (e.g., Griliches, 1989,1990, Hausman et al.,1984, Kortum, 1993).

Patents are also excellent indicators of technological competence because they are directly related to inventiveness (Ahuja, 2000). Empirical studies have shown that patent counts correlate well with new product introductions and invention counts (Basberg, 1987) and that they provide a fairly reliable measure of innovative activity (Acs et al., 2002).

On the other hand, there are limitations to employing patents as measures. Some patents are never exploited commercially; products can be not patentable or not patented for strategic reasons. Moreover, the economic value of patents is highly heterogeneous (Cohen & Levin, 1989).

As Ahuja (2000) pointed out, the degree to which these factors are a problem varies significantly across industries. One challenge is that the propensity to patent may vary as the industry changes, resulting in a potential bias (Levin et al., 1987). I limited this potential bias by sampling in a single industry, so there should be a decent degree of uniformity in the firms' emphasis on innovation and patenting behavior.

The propensity to patent may also differ due to firm characteristics (Griliches, 1990). I attempted to control for this kind of heterogeneity in two ways, as I will explain later in Chapter five. First, I introduced a covariate, Presample Patents (described below). Second, I ran the regression using both firm-fixed and random effects in my estimations.

Patent data was collected from the U.S. Patent and Trademark Office using the National Bureau of Economic Research (NBER) files. Other sources, such as *Corporate Affiliations* and *Who Owns Whom* were also used, as explained in subsection 4.3. As for the measure, I used the application year as the reference year for the patent count. Therefore, granted patents were counted using the year of application. I followed this procedure in order to control for differences caused by delays that may occur in the patent-granting processes. I considered a lag of one year with respect to regressors.

4.4.2 Independent variables

The independent variables in the model are network variables. The dependent variable is focused on the *ego* or the focal buyer. Therefore, one could presume the adoption of an ego network analysis, typically involving the ego's direct ties and the ties among the ego's direct ties (Kilduff &Tsai, 2003). However, the aim here is to go beyond the ego network and relate the ego innovation output with partners of the ego's partners. I basically dealt with nodes up to a path distance of two from the focal buyer. Before presenting the measures, I want to specify that the structure of the network under analysis is the following. There is a focal buyer, namely a motor vehicle company, connected to several suppliers. Each of these suppliers is also linked to buyers and suppliers. I investigated the impact of the supplier's centrality among buyers and suppliers on the focal buyer’s innovation. The network is made up of the following ties: FB-S1 = focal buyer - supplier; S1-S2 = supplier - supplier; S1-B2 = supplier - other buyers; where 1 and 2 signal the path distance of the node from the focal buyer, more specifically, whether the node is reached indirectly by the focal buyer through another node (a supplier) or not. Since I am assessing the impact of the supplier's network on focal buyer's innovation, the direct ties between focal buyer and other buyers are treated as a control variable and not included in the network.

Preliminary remarks

The study aims to relate the alters' networks characteristics to the ego's innovation output. The alters are the suppliers around the ego or the buyer. The focus is on the impact of an alter's centrality in its network on a buyer's innovation. This situation is related to what Borgatti (2002) defined as the *key player problem (KPP):* given a social network, it consists of finding a key players-set of order *k* that is maximally connected to all other nodes. This involves finding nodes that can reach as many remaining nodes as possible via direct links or perhaps short paths.

At first glance, the methods of social network analysis appear to easily solve the key player problem measuring node centrality. However, an approach specifically designed for the key player problem is needed (Borgatti, 2002). The centrality approach consists of computing the centrality of each node in the network, then identifying and choosing the k most central nodes to comprise the key players-set (Borgatti, 2002).

Since many measures of centrality exist, one question that arises is which measure to use. Centrality has been widely recognized in the network literature as an essential structural attribute. In 1948, Bavelas was already testing the hypothesis that central positions confer influence. Since then, the concept has been used in numerous studies. In a classic article, Freeman (1979) deduced three main forms of centrality: degree, closeness, and betweenness.

To deal with the key players problem, we can expect measures based on degree centrality (Borgatti, 2002) to be the most appropriate. Degree centrality expresses a node's connectedness, and it is simply the number of nodes to which a given node is adjacent. The degree centrality of node a is $CD(a) = da$, where d is the number of collaborators adjacent to inventor a. More specifically, a social network is represented here as an undirected, non-valued graph G, consisting of a set of N nodes and a set of K edges connecting pairs of nodes. The graph is described using the so-called adjacency matrix, an $N \times N$ matrix whose entry a_{ij} is 1 if there is an edge between i and j and 0 otherwise. The degree centrality of a node i is defined as

$$D_i = k_i = \sum_{j \varepsilon G} a_{ij}$$

Since in the first step the number of nodes coincides with the number of ties, the previous formula measures degree as the number of direct ties a node has to the other nodes in the network.

In undirected data, actors differ from one another according to how many connections they have. The basic idea is that influential nodes are those with the largest number of direct ties to other nodes in the graph. Hence, assuming that adjacency implies potential for influence, a node with a high degree has the potential to directly influence many other nodes.

The centrality measures are plausible solutions for the key players problem. However, they are not optimal due to the design issue that ultimately arises from the fact that centrality measures were not designed with the key player problem specifically in mind.(Borgatti, 2002). As Borgatti (2002) noted: "If we formulate the key players problem in terms of reaching the most nodes directly, degree centrality is optimal. If we formulate it in terms of reaching the most nodes in up to *m* steps, then we can readily define a new measure of centrality "*m*-reach centrality" that counts the number of nodes within distance *m* of a given node. For key players, we want to measure the distance-based reach of the key players-set into the network around it. Degree, closeness, betweenness and eigenvector centrality measures are not optimal. Hence, we must develop new measures based on the concept of reach. The simplest reach measure, termed *m-reach*, is a count of the number of unique nodes reached by any member of the key player set in m links or less."
This is the principle underlying the measures I used in the model, and the path length considered is of two, going up to the alters' of an ego's alters.

By measuring the impact of the supplier's (alters) characteristics on the focal buyer (ego) innovation, the model used in this study explains a dependent variable referred to as node 1 through the network characteristics of a node 2 that is connected to node 1. The explanatory variable refers to a node different from the one to which the dependent variable refers. However, this discrepancy is artificial because the network characteristics of node 2 can be directly expressed as characteristics of node 1 by using the appropriate measure. This is even more necessary if the explanatory variables refer to a set of nodes connected to node 1 and not just to one node, as in this case (i.e., the focal buyer or node 1 is directly connected to several buyers, node 2, and not just to one). Therefore, an aggregated measure is necessary.

As already explained, the concept underlying the measures utilized is the number of nodes to which a node is connected, at a path distance of one or of n, that is, an extension of the concept of degree. Since I am relating the supplier's centrality with the buyer's output, I needed to use the degree in a more complex form. While degree deals with direct ties, the measure I introduce is like an extension of degree for indirect ties at path length two. In any case, degree centrality is the simplest and most intuitive measure, but it is sometimes considered too rough. I want to specify that in this specific case, closeness[8] and betweenness[9] are less significant, in that they are more global measurements that bring into play the closeness or intermediary role of all network members, not just connections to immediate neighbors (Kilduff &Tsai, 2003). On the contrary, this research focuses on the ego network, even if the perspective is a bit wider (i.e., considering alters of the ego's alters). Moreover, since the focus is on both the gatekeeping function of the ego's partners and on the competition that it can derive from indirect connections, the number of nodes to which the ego's partners are linked seems to matter the most. I also needed to distinguish among different types of nodes to which ego's partners are connected, and the use of betweenness and closeness measures makes it more difficult to take these partitions into account.

Centrality S1-S2

The *Centrality S1-S2* variable measures the average number of suppliers connected to the focal buyer's alters that are suppliers. It expresses the average centrality of the supplier connected to the focal buyer *i* , among other suppliers.

Centrality S1-S2 can be measured as the number of S nodes reached in two steps by the focal buyer divided by the number of S nodes reached in one step by the focal buyer. I refer to this measure as *Reach Efficiency_S*, which can be computed with the following ratio:

$$C_{FBi\ (S1\text{-}S2)} = REACH\ EFFICIENCY_{FBi}\_S = 2\ STEP\ REACH\_S\ /\ 1\ STEP\ REACH\_S$$

$$C_{FBi\ (S1\text{-}S2)} = \sum_{j=1}^{n} S2_j \Big/ \sum_{j=1}^{n} S1_j$$

where

S2 = suppliers at path distance 2 from the focal buyer FB_i

S1 = suppliers at path distance 1 from the focal buyer FB_i

8 Closeness is defined as the degree to which a firm is connected at short distances to all other firms in the network (Freeman, 1979). It is measured as the inverse of the sum of the distances from one point to all other points, normalized by the size of the network. It is based on distance and takes into consideration not only the connections to immediate alters but the closeness to all network actors. In other words, central actors do not rely on others to get information (Bavelas, 1948).

9 Betweenness of a given point to two other points is the capacity of standing on the paths or geodesics (i.e., minimal length paths) that connect them. It explains the intermediary value of a node to all members of a network.

Network reach measures the degree to which any member of a network can reach everyone else in the network. Two-step reach calculates the number of actors that a node can reach in the network in 2 steps; One-step reach calculates the number of actors that a node can reach in the network in 1 step.

In the standard ego network measures computation, two-step reach is a measure that goes beyond ego's one-step neighborhood to report the percentage of all actors in the whole network that are within two directed steps of ego (Hanneman & Riddle, 2005). And reach efficiency (two-step reach divided by size) norms the two-step reach by dividing it by size. $C_{FBi\ (S1\text{-}S2)}$ corresponds conceptually to this measure, but it employs the absolute number of actors instead of the percentage and divides the numerator by (size-1) instead of size. In fact, the size of the ego network is defined as "the number of nodes that one-step out neighbors of ego, plus ego itself" (Hanneman & Riddle, 2005).

Reach efficiency is a measure that shows how many secondary contacts can be reached through each unit of primary contact (Hanneman & Riddle, 2005), and consequently it is very suitable for the analysis of the incoming and outgoing flow of knowledge to the focal buyer through the supplier. It essentially measures a node's outreach to secondary ties that could be significant in transmitting information (Hogset & Barrett, 2007). Reach efficiency indicates that ego's primary contacts are influential in the network. It is the normalization of two-step reach by size. The higher this number, the more primary contacts of ego are relevant in the network. The idea here is to measure how much secondary contact the ego gets for each unit of primary contact. If reach efficiency is high, then the ego is reaching a wider network for each unit of effort invested in maintaining a primary contact. If the ego's neighbors, on average, have a few contacts that ego does not have, the ego has low efficiency (Hanneman & Riddle, 2005).

In the *Centrality S1-S2* variable, two-step reach is computed including all the nodes at a path distance of two, irrespective of a simultaneous presence of a direct tie between the focal buyer and the node at distance two (i.e., some nodes included in the computation of the two-step reach can be reachable by the focal buyer in one step and in two steps simultaneously). S2 can also include the actors in the ego network (i.e., those connected directly to the focal buyer).

As a robustness check, I also specify an alternate measure for the variable *Centrality S1-S2*. It has the same formula but the specification of S2 is different: S2 includes just the nodes that are exactly at a path distance of two from the focal buyer. The nodes that are at a path distance of two from the focal buyer but also connected to it directly are dropped. This corresponds to a narrower measure of the supplier's centrality, and it is the centrality of the supplier S1 in the *external network* consisting of suppliers S2, a network that excludes the ego network. The aim of introducing this alternate measure is to emphasize and isolate the gatekeeping role of the supplier S1, the role of linkage between the ego network and the nodes external to the ego network. This enables one to control for the overlap of two different effects: the knowledge flow available thanks to the supplier's centrality and the higher coordination related to the density in the ego network. The analysis is focused on the first effect, and the second one could introduce a bias in the estimations. I executed the regression using this other measure of centrality; I report the results of this model in chapter five in the robustness check section. Moreover, this measure of centrality assures non-redundancy in the linkages: the supplier at level one is spanning a structural hole between the focal buyer and the supplier at level two. Granovetter (1973) found that information flows through weak ties instead of strong ties. The step reach measure can be computed using Ucinet VI.[10]

Tie strength FB-S1

This variable measures the average strength of the direct ties between the focal buyer and suppliers connected to other suppliers.

$$TS_{FBi\ (FB\text{-}S1'')} = \sum_{j=1}^{n} w * R''_{ij} \Big/ \sum_{j=1}^{n} R''_{ij}$$

where

w = strength of the tie R''_{ij}

[10] Two-step reach with respect to suppliers can be computed in the following ways: (1) running networks|cohesion|geodesic distances; (2) dichotomizing the resulting distance matrix at EQ 2; (3) running networks|cohesion|density| density by groups using the dichotomized matrix as the input network. For row partition, *Identity* is selected, while for the column partition, a dataset indicating the buyer/supplier status of each node is uploaded. The outputs will be, for each node, the number of buyers within 2 links and the number of suppliers within 2 links. Similarly, the one-step reach with respect to suppliers is equivalent to this result but dichotomizes the matrix at EQ1.

R''_{ij}= tie between the focal buyer FB *i* and the supplier *j* (S1") connected directly to the focal buyer. It is the tie between node *i* and node *j* of the network. The measure includes just the suppliers S1" (among the totality of S1) that are connected to other suppliers at the second level (S2). The underlying reason is that this measure is computed to analyse the impact of tie strength with reference to the supplier's centrality among suppliers (S2) on the buyer's innovation (and not also among buyers, B2).

The numerator is the weighted sum of ties between the focal buyer and the suppliers at a path distance of one, connected to other suppliers, while the denominator is just the sum of these ties. In other words, sum of tie strengths FB-S1 / number of ties FB-S1.

Since at the first level (direct ties), the number of nodes coincides with the number of ties, I can also express the measure in terms of degree. In this case, it would be the weighted degree of the focal buyer divided by its degree not weighted.[11] Since the focal buyer's ego network consists of suppliers only, through the degree, I am obtaining the FB-S1 ties. However, I consider the degree to only involve suppliers (S1) that are connected to suppliers at the second level (S2).

When I merged the supply and the alliance networks, I obtained a multiplex network that is valued. The system (Ucinet VI) assigns a value to each type of tie, specifically 1 in case of supply tie, 2 in case of alliance tie, and 3 in case of both alliance and supply tie simultaneously.

<u>Centrality S1-S2 * Tie strength FB-S1</u>

This variable is the interaction of the two measures presented above and is aimed to test the effect of moderation of the direct tie strength of the focal buyer-supplier on the main relation between the supplier's centrality among suppliers and the buyer's innovation.

It can be measured as the multiplication of the aforementioned variables:

$$C_{FBi\ (S1\text{-}S2)} * TS_{FBi\ (FB\text{-}S1'')} =$$

$$= \left(\sum_{j=1}^{n} S2_j \Big/ \sum_{j=1}^{n} S1_j\right) * \left(\sum_{j=1}^{n} w * R''_{ij} \Big/ \sum_{j=1}^{n} R''_{ij}\right)$$

[11] The multiplex network is a valued network If the data are valued, then the degrees will automatically consist of the sums of the values of the ties, as in the numerator of the variable under analysis. To get the not valued degree, as in the denominator, it is sufficient to dicothomize the original valued matrix by assigning 1 for all the values greater than zero and then compute the degree.

The components of the formula have been already defined in the subsections regarding the two terms of the interaction.

Centrality S1-B2

The *Centrality S1-B2* variable measures the average number of buyers connected to the focal buyer's alters, that are suppliers. It expresses the average centrality of the supplier connected to the focal buyer *i* , among other buyers.

Centrality S1-S2 can be measured as the number of B nodes reached in two steps by the focal buyer divided by the number of S nodes reached in one step by the focal buyer. I refer to this measure as *Reach Efficiency B*, which can be computed with the following ratio:

$$C_{FB\mathrm{i}\ (S1\text{-}B2)} = REACH\ EFFICIENCY_{FB\mathrm{i}}\_B = 2\ STEP\ REACH\_B\ /\ 1\ STEP\ REACH\_S$$

$$C_{FB\mathrm{i}\ (S1\text{-}B2)} = \sum_{j=1}^{n} \mathrm{B2}_j \Big/ \sum_{j=1}^{n} \mathrm{S1}_j$$

where

B2 = buyers at path distance 2 from the focal buyer FB_i

S1 = suppliers at path distance 1 from the focal buyer FB_i

Network reach measures the degree to which any member of a network can reach everyone else in the network. Two-step reach calculates the number of actors (i.e., buyers) that a node can reach in the network in 2 steps; One-step reach calculates the number of actors (i.e., suppliers) that a node can reach in the network in 1 step. The same considerations pointed out about *reach efficiency* in the subsection regarding *Centrality S1-S2* are valid here as well. The concept underlying the two variables is the same; they only differ in that *Centrality S1-B2* considers motor vehicle assemblers at the second level, instead of suppliers. This measure is used to assume that the average centrality of the supplier in a network of buyers affects the buyer's innovation. The step reach measure can be computed using Ucinet VI.[12]

[12] Two-step reach with respect to buyers can be computed (1) running networks|cohesion|geodesic distances; (2) dichotomizing the resulting distance matrix at EQ 2; (3) running networks|cohesion|density|density by groups using the dichotomized matrix as the input network. *Identity* is selected for row partition,

Since the ego network only includes suppliers at path distance one from the ego, the buyers at a path distance of two from the focal buyer could be simultaneously placed at path distance one from it. In any case, the direct ties between two buyers will only be included in the control variable. Therefore, the measure I have computed for a robustness check of *Centrality S1-S2* cannot be computed in this case.

Relative tie strength FB-S1/S1-B2

This variable measures the relative average strength of the ties linking the focal buyer to direct partners that are suppliers versus the average strength of the ties linking these suppliers to the other buyers at a path distance of two.

It can be expressed in the following manner:

$$RTS_{FBi\ (FB\text{-}S1'/S1'\text{-}B2)} = TS_{FBi\ (FB\text{-}S1')} \ / \ TS_{FBi\ (S1'\text{-}B2)}$$

where

$$TS_{FBi\ (FB\text{-}S1')} = \sum_{j=1}^{n} k{*}R'_{ij} \ / \ \sum_{j=1}^{n} R'_{ij}$$

$$TS_{FBi\ (S1'\text{-}B2)} = \sum_{j=1}^{n}\sum_{p=1}^{n} q{*}G'_{jp} \ / \ \sum_{j=1}^{n}\sum_{p=1}^{n} G'_{jp}$$

Therefore:

$$RTS_{FBi\ (FB\text{-}S1'/S1'\text{-}B2)} = \left(\sum_{j=1}^{n} k{*}R'_{ij} \ / \ \sum_{j=1}^{n} R'_{ij} \right) / \left(\sum_{j=1}^{n}\sum_{p=1}^{n} q{*}G'_{jp} \ / \ \sum_{j=1}^{n}\sum_{p=1}^{n} G'_{jp} \right)$$

while a dataset indicating the buyer/supplier status of each node for the column partition is uploaded. One of the outputs will be, for each node, the number of buyers within 2 links and the number of suppliers within 2 links. Similarly, the 1 step reach with respect to buyers is equivalent to this result but dichotomizes the matrix at EQ1.

where:

k = strength of the tie R'_{ij}

R'_{ij} = tie between the focal buyer FB *i* and the supplier *j* (S1') connected directly to the focal buyer. It is the tie between node *i* and node *j* of the network. The measure only includes the suppliers S1' (among the totality of S1), which are, in turn, connected to buyers at the second level (B2). The underlying reason is that this measure is only computed to analyze the impact of tie strength with reference to the supplier's centrality among buyers (B2) on the buyer's innovation (and not also among suppliers, S2).

q = strength of the tie G'_{jp}

G'_{jp} = tie between the supplier at step one *j* (S1') and the buyer at step two *p* (B2). It is the tie between node *j* and node *p* of the network.

$\sum k{*}R'_{ij}$ / $\sum R'_{ij}$, respectively, are the sum of tie strengths and the number of ties between the focal buyer and suppliers at a path distance of one that are connected to buyers at a path distance of two. These can also be expressed as the weighted and not weighted degrees of the focal buyer with respect to suppliers connected to buyers at the second step.

$\sum \sum q{*}G'_{jp}$ / $\sum \sum G'_{jp}$, respectively, are sum of tie strengths and number of ties between suppliers at a path distance of one from the focal buyer and buyers at a path distance of two from the focal buyer.

Therefore, in $RTS_{FBi\ (FB\text{-}S1'/S1'\text{-}B2)}$, the average strength of the ties between the focal buyer and its alters— suppliers— connected to other buyers is divided by the average strength of the ties between these suppliers and other buyers. A positive ratio implies an average tie in the first step stronger than the average tie in the second step. In the first step, only suppliers connected to buyers at the second step are included in the measure.

Centrality S1-B2 * Relative tie strength FB-S1/S1-B2

This variable is the interaction of *Centrality S1-B2* and *Relative tie strength FB-S1/S1-B2* which is aimed at testing the effect of moderation of the relative strength of the direct ties focal buyer-supplier versus the strength of the ties supplier-other buyers on the main relation between the supplier's centrality among buyers and the buyer's innovation. It can be expressed as follows:

$$C_{FB\text{i}\ (S1\text{-}B2)} * \text{RTS}_{FB\text{i}\ (FB\text{-}S1'/S1'\text{-}B2)} =$$

$$= \left(\sum_{j=1}^{n} \text{B2}_j \,/ \sum_{j=1}^{n} \text{S1}_j \right) * \left(\sum_{j=1}^{n} \text{k*R}'_{ij} \,/ \sum_{j=1}^{n} \text{R}'_{ij} \right) / \left(\sum_{j=1}^{n} \sum_{p=1}^{n} \text{q*G}'_{jp} \,/ \sum_{j=1}^{n} \sum_{p=1}^{n} \text{G}'_{jp} \right)$$

The components of the formula have been already defined in the subsections regarding the two terms of the interaction.

4.4.3 Control variables

I need to control for the spurious effect of different variables. The control variables considered in the model are listed in the following paragraphs.

S1: This variable is the one step reach, the number of nodes (in this network, namely suppliers) in the ego network of the focal buyer, and it is needed in the model to control for the effect of direct ties on buyer's innovation. Even if the focus is on indirect ties at step two, these connections at step one are still in place and can have an effect. It is the size of the ego-network minus one.

SH Efficiency: This variable measures the structural holes in the ego-network. As density in the ego network decreases, more structural holes are likely to open inside the ego network. This can impact innovation output because it determines the level of coordination inside the ego network and therefore the likelihood of successful and quick implementation of innovative ideas. Hence, I need to control for the level of structural holes. I use *efficiency* as a measure of structural holes. This is based on the *effective size* of the network. The effective size of the network is the number of alters that ego has, minus the average number of ties that each alter has to other alters. If alters are connected to each other, ties in the network are "redundant" because the ego can reach all three alters by reaching any one of them. For instance, if ego is related to 3 alters and each alter is tied to 2 other alters, the effective size of the network is its actual size (3), reduced by its redundancy (2), that is, 1. If alters are not connected among each other, their effective size is 3 (Hanneman & Riddle, 2005). Efficiency norms the effective size of ego's network by its actual size. That is, what proportion of ego's ties to its alters are "non-redundant." Efficiency expresses how much contribution ego is getting for each unit invested in using ties (Hanneman & Riddle, 2005). I can use Ucinet VI to calculate these measures through the commands *Network >EgoNetworks >Structural Holes*.

ROA: This variable is the measure of profitability. It controls for the possibility that higher innovation is driven by higher profitability. This is measured as the ratio of income to total assets.

R&D Intensity: R&D expenditures are likely to be a significant determinant of innovative outcomes. An appropriate control would be to include only the R&D expenditures on motor vehicle- related businesses rather than corporate R&D. Unfortunately, business-level research expenditures are not commonly reported. R&D intensity is then computed as the ratio of a firm's R&D investment to its revenue.

Current ratio: This variable measures liquidity. It is computed as the ratio of current assets to current liabilities.

Debt to equity: This value reflects the leverage characteristics of a firm and controls for financial motivations that impact innovative performance. It is measured as the ratio of total liabilities/(total assets - total liabilities).

Emp: This variable is the number of employees, and it is a measure of size used in prior research (e.g., Goerzen and Beamish, 2005). Firms of different sizes innovate differently. In the classical Schumpeterian argument, companies’ innovation performance increases more than proportionally with firm size because large firms simply have more resources.

Patents S1: This variable represents the patents count of the suppliers linked directly to the focal buyer in the ego network of the focal buyer. This control is aimed at considering the technical capabilities and innovativeness of the supplier independently from its network variables. This is in line with the supplier-buyer literature, which focuses on the firm-level characteristics of the supplier. I control for this spurious effect.

Supply ties FB-B: This variable measures the number of supply ties between two motor vehicle companies. In the sample, there were very few cases in which one motor vehicle firm supplies another one using its internal component manufacturing division. I have kept these cases separate, in the form of a control variable, because they are an exception that could have the effect of mixing up too many components in the network and alter the significance and interpretation feasibility of the network variables. As already explained, I have executed the regression model for a robustness check with and without including motor vehicle companies that do not have operating activities in the United States. Accordingly, this measure in one model will include these companies, in the other, it will not.

Horizontal ties FB-B: This variable measures for each motor vehicle firm, the number of alliance ties (horizontal ties) with other motor vehicle companies in which it is involved. These ties have been kept as a control variable and removed from the network for at least four reasons. First, the focus of the analysis is the impact of the supplier's network on the buyer's innovation output; therefore, this involves buyer-supplier ties and supplier-supplier ties but not buyer-buyer ties. Second, I maintain consistency with the removal of the supply ties between two motor vehicle companies in the superimposition of the supply and alliance network. Third, without a single kind of actor in the direct tie with the focal buyer, too many different effects could have been in place simultaneously. Fourth, while considering the competition of other buyers mediated by the supplier, we think about the flow of knowledge and the leakiness of knowledge. If we introduce direct alliance ties between motor vehicle companies, some competitor buyers will be no longer considered as reached at the second step through the supplier; instead, they are considered to be reached at the first step directly. However, this will lead to biased conclusions or predictions. While in a direct tie, the parties can safeguard against direct transmission of knowledge by stipulating norms for information exchange in a contract, limiting the scope of collaboration and creating rules about what can and cannot be discussed and shared, thus, the parties will have little control on an indirect transmission through a shared supplier. Therefore, the buyer should in any case be considered a node reached at step 2. Being aware of a strong assumption, I have built the network by also keeping these relationships inside and I ran the regression models. The results are unchanged in terms of signs and significance.

Presample patents: This variable is the number of each firm’s patents in the three years before the sampling period. This is a measure of past innovativeness. As pointed out by Ahuja (2000), the choice of a three- to five-year time frame to measure technical capital is consistent with studies of R&D depreciation (Griliches, 1984). This variable it is a measure of past innovativeness that serves as a fixed effect for the underlying innovativeness of the firm (Ahuja & Katila, 2001).

CHAPTER V - Results

This Chapter presents the results of the analyses carried out to test the hypotheses illustrated in Chapter 3. A short overview of the key results is presented at the beginning. Subsequently, an explanation of the line of reasoning underlying the choice of the model is provided. Finally, the detailed results will be presented, and robustness checks will be described. Some issues regarding the statistical method used in testing the hypotheses will be analyzed.

5.1 Summary of key results

The key results are summarized in the following table.

Table 1.1 Summary of key Results

Hypothesis	*Dependent Variable*	*Independent Variable*	*Predicted*	*Summary*
One	*Patents*	*Centrality S1-S2*	+	*Supported*
Two	*Patents*	Centrality S1-S2 * Tie strength FB-S1	-	*Supported*
Three	*Patents*	Centrality S1-B2	-	*Supported*
Four	*Patents*	Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	+	*Supported*

All the hypotheses are based on the same dependent variable; that is, the focal buyer's patents count. The first and the third hypotheses investigated the impact of the supplier's centrality in the network of suppliers and buyers on the buyer's innovation output, predicting a positive and negative effect respectively. These two main effects are supported by the statistical analysis.

Two moderation effects were predicted to intervene in this process. Hypothesis two predicted that the strength of focal buyer-supplier ties has an effect of negative moderation on the causal relation between the supplier's centrality among suppliers and the focal buyer's innovation. This negative effect is supported. Hypothesis four predicted that the relative strength of the tie focal buyer-supplier versus the strength of the tie supplier-other buyers has a positive moderation effect on the causal relation between the supplier's centrality among buyers and the focal buyer's innovation. This positive effect is supported by the data.

The basic estimation was supplemented by robustness checks, along three main dimensions: sensitivity to statistical estimation utilized, sensitivity to construct measurement and sensitivity to sampling choices, to control for potential biases. These will be explained in the robustness check section. The overall findings provide strong evidence that the model is robust to alternative specifications, that led essentially the same pattern of coefficients and significance.

In addition, a statistical analysis has been executed, computing the patents - in the cases of co-patenting -in two different ways, assigning 1.0 or 0.5 to each joint patent as already explained. In the chapter, the main model is implemented using 0,5, to avoid spurious inflation of patent counts through double counting of patents; the other is reported in the robustness check section, marked with "*a)* and *copatenting 1.0"*. Both results are reported; they appear to be highly similar. There is no change in the significance and in the signs of the resulting coefficients. Also, in the robustness checks, four additional models are reported that differ from the first one at the measurement specifications or sample level, or for multicollinearity check. The case "*a)* and *copatenting 1.0"* is reported also for each of these new models.

5.2 The model

As already explained, the dependent variable, innovation output, as represented by patent counts, is a count variable and takes only non-negative integer values. The linear regression model assumes homoskedastic normally distributed errors. Since these assumptions are violated with count variables, a *count model* will be used: a *Poisson or Negative binomial regression,* depending on the presence of overdispersion in the data (standard deviation of data exceeds the mean) (Hausman, Hall, & Griliches, 1984).

As we can see from the descriptive statistics table (Table 1.2), the mean of the dependent variable does not equal the variance. Therefore, we can suspect the presence of overdispersion. The value of the alpha of 2,013 clearly confirms this. It is positive and significant.

Therefore, I should employ a negative binomial model. In order to establish whether the fixed effect or the random effect one should be executed, I ran the Hausman test. The results show that I can choose the negative binomial random effect. I have implemented the regression with six different statistical estimations to check for robustness, these produce consistent results among one another, both in signs and in significance. This is a good outcome; the hypotheses seem to be strongly supported by the data. Of course, the level of significance is higher in the Poisson models, with particular respect to the controls. I report the results in the following pages.

5.3 Results

In the following subsections, I briefly present the results of my main model. Section 5.3.1 details the descriptive statistics and correlation matrix of the variables used in the research, while section 5.3.2 presents and discusses the results of the hypotheses testing.

5.3.1 Descriptive statistics and correlation matrix

In the main model that excludes motor-vehicle companies not operating in the United States, the network includes 1,089 nodes in 1994, 1,177 nodes in 1996, 1,120 nodes in 1998, 1,052 nodes in 2001, and 1,007 nodes in 2004. However, since the dependent variable is related to the motor vehicle companies, the regression has been implemented just on the motor vehicle assemblers. In the end, after the deletion of firms presenting missing values in all the years of the panel, I obtained 37 assemblers and 156 observations over the five years analyzed.

Table 1.2 reports descriptive statistics and correlations for the variables considered in the regression models. As a general remark, the results of the correlation seem to be in line with what one would expect. I can briefly summarize the main aggregate outcome, looking at three aspects: correlation between dependent and independent variables, correlation of independent variables amongst themselves, and identification of the pairs of variables showing the highest correlations. In the table for three variables: the dependent variable *Patents count x year,* the *Patents S1* and the

Presample patents, the values computed—scoring patents 0.5 and 1 in case of copatenting—are both included (for the 0.5 case, the word copatenting is written in parenthesis).

Dependent and independent variables are low correlated, in all. The correlation between the independent variables amongst themselves is not particularly high, except for the correlation between the interaction variables (hp 2 and hp4) and the variables of the main effects (hp1 and hp 3). More specifically, the pairs of independent variables have the following correlation coefficient, respectively: *Centrality S1-S2* and *Centrality S1-B2*: 0.430; *Centrality S1-S2* and (*Centrality S1-B2*Relative tie strength FB-S1/S1-B2*)= 0.479; (*Centrality S1-S2*Tie strength FB-S1*) and *Centrality S1-B2*=0.424; (*Centrality S1-S2*Tie strength FB-S1*) and (*Centrality S1-B2*Relative tie strength FB-S1/S1-B2*)=0.504. The values are almost aligned, with a range of variation of between 0.424 and 0.504. On the contrary, as can be expected, the correlation is high between the variables of hp1 and hp2; i.e. *Centrality S1-S2* and (*Centrality S1-S2*Tie strength FB-S1*)= 0.977 and between the variables of hp3 and hp4, i.e. *Centrality S1-B2* and (*Centrality S1-B2*Relative tie strength FB-S1/S1-B2*)=0.985. This, even if it regards the interactions, raises the possibility of high collinearity and low power in the testing of the hypotheses. When two regressors are very closely related, it is hard to untangle their separate effects on the dependent variable. When one increases, the other increases simultaneously. It is hard to specify the increase to which we attribute the increase in the dependent variable.

To check for multicollinearity, I mean-deviated the two variables *Centrality S1-S2* and *Tie strength FB-S1*, as well as the two variables *Centrality S1-B2* and *Relative tie strength FB-S1/S1-B2* before entering them into the interaction. I recomputed the components of the interaction, subtracting the mean from their values, updating the resulting value of the interaction and executing the model again. The correlation between the two components remains unchanged, but the correlation between the interactions and *Centrality* decreases, changing from 0.977 to 0.356 and from 0.985 to 0.238 (as shown in Table 1.3). The significant outcome is that the results of the model are unchanged in the pattern of signs and significance. This new model is reported in the Robustness Checks section of the chapter in Table 1.8, column 5. This shows that the problem of multicollinearity is overcome. Finally, the correlation among the components of the interactions: *Strength FB-S1* and *Relative tie strength FB-S1/S1-B2* with the hypothesized independent variables is low, ranging respectively from -0.061 to 0.440 and from 0.279 to 0.534.

I highlight the pairs of variables showing the highest correlation coefficients. Most of them are very consistent with what can be presumed in principle, or with other results. The high correlation (0,611) between *Centrality S1-S2* with *SH efficiency*, the measure of structural holes in the ego network, is related to the measure of *Centrality S1-S2*, which involves the ties in the ego network, which in turn reveals whether structural holes are present or not. For this reason, I have implemented a new regression model as a robustness check, a model obtained by excluding from the centrality measure the ties among actors inside the ego-network; that is, an indirect measure of structural holes. The achievement of similar results in the two regression models assures that I am not introducing duplications in the measurement that are capable of creating bias. Examples of other high correlations are between *Presample patents (copatenting)* and the dependent variable, *Patents count x year (copatenting)* with a value of 0.749; between *Patents S1* (i.e. patents count of the suppliers in the ego network) and *S1* (i.e. number of suppliers in the ego network) with a value of 0.749; between *Emp* (i.e. number of employees) and *S1*, with a value of 0.793. If *Emp* is a proxy for size, this is just expressing that larger firms tend to have a higher number of suppliers, which is highly conceivable. Finally, as expected, the three variables computed attributing 0.5 to the copatenting case are highly correlated with the corresponding three variables computed assigning 1 to it (with a correlation of 0.999), but they are used in different regression models; therefore, this is obviously not an issue.

The table, which reports the results for the main model and for the model to check for multicollinearity in the case of the interaction variables, appears below.

Table 1.2 - Model1 - Descriptive statistics

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 Patents count x year	105,770	201,820	1,000																				
2 Patents count x year (copatenting)	103,510	199,710	0,999	1,000																			
3 Centrality S1-S2	6,230	6,450	-0,109	-0,104	1,000																		
4 Tie strength FB-S1	1,030	0,190	0,026	0,026	0,372	1,000																	
5 Centrality S1-S2 *Tie strength FB-S1	6,890	7,920	-0,114	-0,110	0,977	0,440	1,000																
6 Centrality S1-B2	1,880	2,720	-0,219	-0,215	0,430	-0,061	0,424	1,000															
7 Relative tie strength FB-S1/S1-B2	1,000	0,090	-0,063	-0,063	0,366	0,488	0,534	0,279	1,000														
8 Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	1,960	2,920	-0,212	-0,209	0,479	0,015	0,504	0,985	0,417	1,000													
9 SH Efficiency	0,970	0,060	0,090	0,088	-0,612	-0,321	-0,666	-0,200	-0,393	-0,283	1,000												
10 S1	124,920	214,780	0,319	0,304	-0,371	0,001	-0,345	-0,366	-0,092	-0,356	0,179	1,000											
11 Supply ties FB-B	0,920	2,000	0,323	0,303	-0,177	0,071	-0,159	-0,254	-0,018	-0,249	0,093	0,622	1,000										
12 Horizontal ties FB-B	2,290	2,710	0,219	0,204	-0,266	0,114	-0,239	-0,447	-0,063	-0,434	0,148	0,594	0,419	1,000									
13 Presample patents	382,540	769,900	0,743	0,748	-0,219	0,042	-0,201	-0,264	-0,033	-0,252	0,093	0,518	0,385	0,348	1,000								
14 Presample patents (copatenting)	379,690	764,760	0,744	0,749	-0,219	0,042	-0,200	-0,264	-0,033	-0,252	0,093	0,518	0,384	0,348	1,000	1,000							
15 Patents S1	2942,130	3227,240	0,447	0,433	-0,369	0,051	-0,347	-0,527	-0,162	-0,513	0,166	0,751	0,543	0,691	0,455	0,455	1,000						
16 Patents S1 (copatenting)	2865,730	3134,000	0,447	0,433	-0,369	0,053	-0,346	-0,529	-0,163	-0,514	0,165	0,749	0,542	0,693	0,455	0,455	0,999	1,000					
17 emp	92,360	131,810	0,316	0,300	-0,285	0,061	-0,261	-0,367	-0,056	-0,355	0,140	0,793	0,672	0,558	0,465	0,464	0,670	0,670	1,000				
18 ROA	0,020	0,070	-0,038	-0,038	-0,137	-0,230	-0,174	0,188	-0,220	0,152	0,052	-0,022	-0,055	-0,198	-0,181	-0,181	-0,096	-0,096	-0,041	1,000			
19 current ratio	1,350	0,660	-0,213	-0,214	0,110	-0,109	0,055	0,508	-0,169	0,451	0,039	-0,244	-0,102	-0,310	-0,279	-0,279	-0,329	-0,329	-0,196	0,269	1,000		
20 debt to equity	2,600	11,210	0,168	0,168	-0,095	0,063	-0,062	-0,171	0,055	-0,148	0,090	0,287	0,178	0,241	0,236	0,235	0,316	0,316	0,267	0,036	-0,256	1,000	
21 R&D Intensity	0,030	0,020	0,215	0,210	-0,269	0,044	-0,271	-0,294	-0,150	-0,296	0,201	0,325	0,222	0,323	0,244	0,243	0,417	0,418	0,405	0,087	-0,116	0,300	1,000

Table 1.3 - Model1 - Descriptive statistics - multicollinearity check

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 Patents count x year	105,770	201,820	1,000																				
2 Patents count x year (copatenting)	103,510	199,710	0,999	1,000																			
3 Centrality S1-S2	0,000	6,450	-0,109	-0,104	1,000																		
4 Tie strength FB-S1	0,000	0,199	0,026	0,026	0,372	1,000																	
5 Centrality S1-S2 *Tie strength FB-S1	0,477	1,758	-0,122	-0,121	0,356	-0,132	1,000																
6 Centrality S1-B2	0,000	2,720	-0,219	-0,215	0,430	-0,061	0,330	1,000															
7 Relative tie strength FB-S1/S1-B2	0,000	0,090	-0,063	-0,063	0,366	0,488	0,675	0,279	1,000														
8 Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	0,068	0,396	-0,026	-0,026	0,411	0,323	0,737	0,238	0,722	1,000													
9 SH Efficiency	0,970	0,060	0,090	0,088	-0,612	-0,321	-0,457	-0,200	-0,393	-0,538	1,000												
10 S1	124,920	214,780	0,319	0,304	-0,371	0,001	-0,150	-0,366	-0,092	-0,063	0,179	1,000											
11 Supply ties FB-B	0,920	2,000	0,323	0,303	-0,177	0,071	-0,095	-0,254	-0,018	-0,074	0,093	0,622	1,000										
12 Horizontal ties FB-B	2,290	2,710	0,219	0,204	-0,266	0,114	-0,152	-0,447	-0,063	-0,092	0,148	0,594	0,419	1,000									
13 Presample patents	382,540	769,900	0,743	0,748	-0,219	0,042	-0,105	-0,264	-0,033	-0,022	0,093	0,518	0,385	0,348	1,000								
14 Presample patents (copatenting)	379,690	764,760	0,744	0,749	-0,219	0,042	-0,105	-0,264	-0,033	-0,022	0,093	0,518	0,384	0,348	1,000	1,000							
15 Patents S1	2942,130	3227,240	0,447	0,433	-0,369	0,051	-0,204	-0,527	-0,162	-0,075	0,166	0,751	0,543	0,691	0,455	0,455	1,000						
16 Patents S1 (copatenting)	2865,730	3134,000	0,447	0,433	-0,369	0,053	-0,204	-0,529	-0,163	-0,075	0,165	0,749	0,542	0,693	0,455	0,455	0,999	1,000					
17 emp	92,360	131,810	0,316	0,300	-0,285	0,061	-0,138	-0,367	-0,056	-0,062	0,140	0,793	0,672	0,558	0,465	0,464	0,670	0,670	1,000				
18 ROA	0,020	0,070	-0,038	-0,038	-0,137	-0,230	-0,101	0,188	-0,220	-0,079	0,052	-0,022	-0,055	-0,198	-0,181	-0,181	-0,096	-0,096	-0,041	1,000			
19 current ratio	1,350	0,660	-0,213	-0,214	0,110	-0,109	-0,089	0,508	-0,169	-0,111	0,039	-0,244	-0,102	-0,310	-0,279	-0,279	-0,329	-0,329	-0,196	0,269	1,000		
20 debt to equity	2,600	11,210	0,168	0,168	-0,095	0,063	0,035	-0,171	0,055	0,064	0,090	0,287	0,178	0,241	0,236	0,235	0,316	0,316	0,267	0,036	-0,256	1,000	
21 R&D Intensity	0,030	0,020	0,215	0,210	-0,269	0,044	-0,236	-0,294	-0,150	-0,091	0,201	0,325	0,222	0,323	0,244	0,243	0,417	0,418	0,405	0,087	-0,116	0,300	1,000

5.3.2 Hypotheses Testing

Tables 1.4 and 1.5 present the results of the main model. Table 1.4 introduces the variables of the hypotheses successively in the negative binomial RE model, which has proven to be the most appropriate for reasons that I will explain later. Table 1.5 presents the full set of coefficients on innovation, comparing the results of the regression executed using different potential statistical models. The main model scores 0.5 the patents in the case of co-patenting. I present the same tabs but computed scoring 1.0 the patents in the case of co-patenting in the robustness checks.

In Table 1.4, in the negative binomial specification, I first introduce the variables regarding the two main effects on the buyer's innovation output (investigated by hp 1 and 3); subsequently, I add the moderation effects (investigated by hp 2 and hp4). Sign and significance of the coefficients remain steady when adding new variables to the first one.

In Table 1.5, I present the full model with different statistical estimators. This visualization is useful for comparisons. It is evident that while in the Poisson specification, the control variables are generally significant, they become progressively insignificant in the negative binomial specification. This is quite understandable. The negative binomial is inflating the standard errors, which become bigger and bigger, dropping down the significance of the coefficients. This process is even more enhanced by the presence of the presample variable.

I briefly explain the process that led me to the choices of the most appropriate model. I have included six statistical specifications (in the columns of Table 1.5), following Cameron and Trivedi (2010); they explained panel models for count data, mentioning four panel Poisson estimators - pooled Poisson with cluster-robust errors, population-averaged Poisson, Poisson random effects (RE), and Poisson fixed effects (FE) - along with negative binomial models in which I again distinguish in random effects (RE) and fixed effects (FE).

Cameron and Trivedi (2010) asserted that in the use of pooled Poisson model, getting cluster-robust standard errors with cluster on individuals (i) has the effect to control for both overdispersion and correlation overtime for given i. The authors provided an example, showing that with respect to the default non-cluster-robust, the default standard errors are one-fourth as large and that the default t-statistics are four times as large. Therefore the population-averaged Poisson is also executed with cluster-robust standard errors.

Poisson regression is the standard or base count response regression model (Hilbe, 2007). Since the model plays a central role in count response modeling, I began with that. This provided a base case for comparison with more sophisticated models. The results of the estimations are first presented in all tables in column 1 pooled Poisson and then in columns 2, 3, and 4 for the panel Poisson models.

A primary assumption of this model is the equidispersion or the equality of the mean and the variance functions. On the contrary, overdispersion occurs when the value of the variance exceeds that of the mean, causing Poisson standard errors to be smaller than they should and recognizing the coefficient as significant even when that is not the case. Overdispersion is due to heterogeneity among the observational units that is not accounted. The overdispersion issue can be tackled in three basic ways: reducing the error variance, correcting the standard errors, and adopting the negative binomial model.

For instance, for the error variance, overdispersion can occur when the model omits important explanatory predictors. One remedy for a model when faced with apparent overdispersion is adding an appropriate predictor. I applied this by introducing the variable *Presample patents* to capture unobserved heterogeneity in the firm’s propensity to innovate. Presample was automatically excluded from the fixed effects (FE) estimations. This is the reason it is left blank in all tables.

The negative binomial regression is the standard way to deal with overdispersion. Every application of the negative binomial model is in response of perceived overdispersion in a Poisson model (Hilbe, 2007). The negative binomial model allows for the variance that exceeds the mean. After the Poisson, I ran a negative binomial specification to check for the presence of overdispersion by determining if the value of the dispersion parameter α was statistically different from zero. The coefficient of the dispersion parameter α was used to determine whether the data were characterized by heterogeneity or not. If α was not statistically different from zero, then data are to be modeled as Poisson; if there is a statistically significant difference, then a negative binomial model specification provided a better fit with the data (Greene, 1995). In the case of the main model, the parameter α is positive and significant—with a value of 2,013—indicating that the data are characterized by overdispersion, and the Poisson specification is possibly inaccurate.

I used the negative binomial specification to test the hypotheses. The result is that the pattern of signs and significance are not altered with respect to the Poisson estimations.

Even when adopting the negative binomial estimations, choice of the utilization of random effect (RE) or fixed effect (FE) has to be done. To decide, I ran the Hausman Test. The test is not significant (with a resulting Prob > chi2 = 0.9997). This implies that the use of random effect is allowed. I will focus on these results to test the hypotheses.

As the tables show, the results support the hypotheses. The sensitivity to statistical approach test reveals that all the six estimations produced similar results in terms of signs and significance with respect to the hypothesized regressors; this strongly support the predictions made in the hypotheses. I report the results of the negative binomial in column 6 of Table 1.5 or in Table 1.4.

Hypothesis One predicted that the supplier's centrality in the network of suppliers would be associated to superior buyer's innovative output. This hypothesis was supported, being the resulting coefficient positive and significant at level $p < 0,01$. Hypothesis Two predicted that the strength of the direct tie between the focal buyer and the supplier would negatively moderate the main effect presented in Hypothesis One. The hypothesis is tested with an interaction term and is supported. The hypothesis found support, and the coefficient is negative and significant at level $p < 0,01$. Therefore, the higher this strength, the lower the positive impact of the supplier's centrality on buyer's innovation output. Hypothesis Three predicted that the supplier's centrality in the network of buyers would be associated to the lower buyer's innovative output. The hypothesis was strongly supported, with a negative coefficient that is highly significant at level $p < 0,001$. Hypothesis Four predicted that the relative strength of the tie between the focal buyer and the supplier versus the strength of the ties between this supplier and other buyers positively moderates the main effect shown in hypothesis Three. The hypothesis found strong support, with a positive coefficient that is highly significant at level $p < 0,001$. In conclusion, the theoretical framework is supported by the data.

As for the control variables in the full model (column 6 of Table 1.5, or Table 1.4), *Patents s1*, *Presample patents*, and *Horizontal ties* are significant at level $p < 0.001$. *Patents s1* is positive, and it is the count of the patents granted to suppliers directly linked to the focal buyer. The higher the innovativeness of the suppliers connected to the buyer, the higher the buyer's innovations. This result is in line with what is broadly shown in previous literature that identifies firm level characteristics of the supplier, such as technical capability, as determinants of the buyer's performance. *Presample patents* represents the past innovativeness of the focal buyer. It explains the unobserved firm's propensity to invent; it is positive, and its significance proves that it has been wise to introduce this additional predictor inside the model to control for the firm's unobserved heterogeneity. *Horizontal ties FB-B* is the number of horizontal alliances of the focal buyer with other buyers; that is, other motor vehicle companies. The impact is negative. This finding can be further investigated; the underlying principle explaining the effect could be that the less-innovative firms tend to connect with other assemblers to enhance their innovative skills. Moreover, the variable *ROA* is positive even with a very low significance ($p < 0.1$). Firms with high financial performance are able to achieve higher innovation output due to more availability of resources.

If we consider that the negative binomial estimation substantially inflates the standard errors, reducing significance, we could look at the value of the Poisson estimation to see which other variables were significant. The additional variables all show a significance of $p < 0.001$. *S1* is positive, meaning that the higher the number of the suppliers directly connected to the buyer, the higher the innovation output. One explanation for this is availability of a wider set of resources in the case of a wider network of suppliers. The *Debt to equity* is negative. Higher values of this ratio are likely to signify pressure to curtail further expansion, thereby reducing developmental activities such as innovative efforts. *Current ratio* is negative. One possible explanation could be that this reveals adoption of a short-term perspective, where the focus on long-term plans of development, such as innovation, is lower. *Emp*, the number of employees, is negatively associated with the firm's innovation output. Since *Emp* is a proxy for size, this is a bit counterintuitive; however if we refer to the innovation function, one possible explanation could be the congestion effect that captures the dependence of research productivity on the number of people searching for new ideas: If more people do research simultaneously, efforts might be duplicated or wasted; higher numbers of researchers might reduce the overall innovative output. Finally, *Supply ties FB-B* is negative. This refers to motor vehicle companies that are buying supply components from other motor vehicle companies. The negative effect could be due to lower levels of specialization of the motor vehicle companies in that type of business - that is, not their core business - or could also be explained similarly to the *Horizontal ties FB-B* variable.

Finally, the coefficient related to the strength of the ties, which are the components of the two interaction terms *Tie strength FB-S1* and *Relative tie strength FB-S1/S1-B2*, are both insignificant. This seems quite understandable because we are dealing with a complex network in which strength has an impact on the extent to which the supply can or cannot convey certain kinds of benefits to the focal buyer. The effect of the strength is a function of other specifications regarding the supplier, such as its contacts and the knowledge it can consequently provide; therefore, it has an effect when in combination with an indicator of the supplier's centrality. In Table 1.4 (and 1.6, in case of copatenting =1.0) I report the results of the Log Likelihood-ratio test. The test statistic used in the test, approximately Chi-squared distributed with degrees of freedom (df) equal to the difference of the degrees of freedom of the compared model (df2-df1), is always statistically significant. Therefore the less restrictive models, i.e. those with the introduction of more variables, fit the data significantly better than the more restrictive models (from column 2 to 4 of Table 1.4 and 1.6). All the Table I referred to in the present section are reported below.

Table 1.4 - Model 1 - Panel Negative Binomial Re

Variable				
Centrality S1-S2		0 046**	0,071***	0,446**
		(0,016)	(0,021)	(0,144)
Tie strength FB-S1				0,233
				(0,829)
Centrality S1-S2 * Tie strength FB-S1				-0,342**
				(0,129)
Centrality S1-B2			-0,157*	-1,494***
			(0,077)	(0,422)
Relative tie strength FB-S1/S1-B2				0,017
				2,003)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2				1,303***
				(0,389)
Constant	-3,654	-2,994	-6,440*	-1,398
	(2,504)	(2,382)	(2,749)	(1,858)
SH efficiency	4,585°	3,561	6,897*	1,602
	(2,631)	(2,482)	(2,827)	(1,219)
S1	-0,002	-0,001	-0,002°	-0,002
	(0,001)	(0,001)	(0,001)	(0,001)
ROA	2,033*	1,737*	1,969*	1,499°
	(0,869)	(0,845)	(0,826)	(0,848)
R&D Intensity	3,868	7,304	5,845	3,046
	(6,921)	(6,683)	(6,206)	(6,211)
Current ratio	-0,463*	-0,526*	-0,357	-0,319
	(0,200)	(0,207)	(0,227)	(0,230)
Debt to equity	-0,011	-0,008	-0,006	-0,005
	(0,010)	(0,010)	(0,009)	(0,009)
Emp	-0,001	-0,002°	-0,001	-0,001
	(0,001)	(9,2e04)	(9,2e-04)	(9,0e-04)
Patents s1	2,6e-04***	2,8e-04***	2,8e-04***	2,8e-04***
	(3,4e-05)	(3,4e-05)	(3,2e-05)	(3,3e-05)
Supply ties FB-B	-0,005	-0,003	-0,006	-0,005
	(0,016)	(0,014)	(0,013)	(0,013)
Horizontal ties FB-B	-0,193***	-0,226***	-0,220***	-0,232***
	(0,048)	(0,040)	(0,034)	(0,036)
Presample patents	0,001*	0,001***	0,001***	0,001***
	(5,2e-04)	(4,3e-04)	(3,6e-04)	(3,9e-04)
N, obs	156	156	156	156
Log Likelihood	-657,019	-653,957	-651,678	-646,142
Chi Sq/df		6,120/1*	4,560/1*	11,070/4*
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis				

Table 1.5 - Model 1 - Full Model

Variable	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Centrality S1-S2	0,989**	0,759***	0,761***	0,986*	0,502***	0,446**
	(0,366)	(0,054)	(0,053)	(0,406)	(0,156)	(0,144)
Tie strength FB-S1	-0,580	1,242°	1,315*	-0,092	-0,316	0,233
	(0,862)	(0,671)	(0,655)	(0,297)	(0,867)	(0,829)
Centrality S1-S2 * Tie strength FB-S1	-0,802*	-0,679***	-0,681***	-0,866*	-0,416**	-0,342**
	(0,330)	(0,051)	(0,050)	(0,377)	(0,141)	(0,129)
Centrality S1-B2	-2,530*	-2,158***	-2,174***	-2,952**	-1,633***	-1,494***
	(1,113)	(0,175)	(0,174)	(1,111)	(0,477)	(0,422)
Relative tie strength FB-S1/S1-B2	5,012	-2,376***	-2,416***	-0,629	0,190	0,017
	(4,182)	(0,663)	(0,656)	(3,953)	(2,091)	(2,003)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,141*	2,115***	2,127***	2,739**	1,501***	1,303***
	(1,011)	(0,167)	(0,165)	(1,009)	(0,452)	(0,389)
Constant	-6,022		4,690***	2,096	-0,328	-1,398
	(4,779)		(0,673)	(3,426)	(2,037)	(1,858)
SH efficiency	3,864	-0,437	-0,408	1,786	0,847	1,602
	(3,690)	(0,428)	(0,426)	(2,146)	(1,379)	(1,219)
S1	-9,2e-04	0,005***	0,004***	-0,001	3,7e-04	-0,002
	(0,001)	(7,2e-04)	(7,0e-04)	(0,001)	(0,001)	(0,001)
ROA	5,573*	1,858***	1,828***	2,596°	-0,683	1,499°
	(2,588)	(0,297)	(0,296)	(1,349)	(1,184)	(0,848)
R&D Intensity	18,916°	1,988	2,201	8,400	0,567	3,046
	(9,974)	(1,598)	(1,592)	(5,955)	(7,374)	(6,211)
Current ratio	0,104	-0,241***	-0,250***	-0,035	-0,029	-0,319
	(0,258)	(0,068)	(0,068)	(0,203)	(0,242)	(0,230)
Debt to equity	-0,007	-0,015***	-0,015***	-0,010	-0,029*	-0,005
	(0,015)	(0,004)	(0,004)	(0,006)	(0,014)	(0,009)
Emp	-0,001	-0,003***	-0,003***	-7,9e-04	-1,7e-04	-0,001
	(0,001)	(3,6e-04)	(3,5e-04)	(0,001)	(0,001)	(9,0e-04)
Patents s1	2,2e-04**	2,7e-04***	2,7e-04***	2,5e-04***	2,6e-04***	2,8e-04***
	(7,8e-05)	(8,9e-06)	(8,8e-06)	(4,7e-05)	(4,1e-05)	(3,3e-05)
Supply ties FB-B	0,006	-0,020***	-0,018***	0,008	-0,007	-0,005
	(0,029)	(0,005)	(0,005)	(0,019)	(0,028)	(0,013)
Horizontal ties FB-B	-0,056	-0,228***	-0,228***	-0,148***	-0,126**	-0,232***
	(0,055)	(0,009)	(0,009)	(0,046)	(0,048)	(0,036)
Presample patents	8,9e-04***		0,001*	8,6e-04***		0,001***
	(1,0e-04)		(5,2e-04)	(1,15e-04)		(3,9e-04)
N, obs	156	145	156	156	145	156
Log Likelihood	-6216,928	-1055,206	-1280,508		-417,485	-646,142

° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis

$\alpha = 2{,}013$ Hausman Prob>chi2 = 0.9997

5.4 Robustness checks

In this section, I present several alternative specifications to the main model. I took several steps to ensure the robustness of my results along three main dimensions: sensitivity to statistical estimation utilized, sensitivity to construct measurement, and sensitivity to sampling choices. Sensitivity to statistical estimation employed was tested through the execution of the regression according to different statistical specifications (e.g., Poisson, negative binomial, etc.). Sensitivity to construct measurement was tested considering alternative measures for the key variables. Sensitivity to sampling choices was tested by running the regression using multiple samples, excluding or including some types of firms. Moreover, computation has been carried out on the dependent variables in two different ways with respect to co-patenting. Finally, the correction for multicollinearity between the key variables and the interaction terms (explained in descriptive statistics section) has been carried out, running the model again. Table 1.8 and 1.9 summarize the results of the five regressions, executed using Panel negative binomial RE, as in the main model.

First, I report in Table 1.6 and 1.7 the results of the main model, re-executed by assigning 1.0 to patents that were granted to more than one firm (co-patenting) to avoid spurious inflation of patent counts through double-counting.

The sensitivity to statistical estimation is something I have applied to all the models: to the main models as well as to the models for robustness check. In fact, for each table, there are six columns corresponding to different estimations: pooled Poisson with cluster-robust errors, panel Poisson random effects (RE), panel Poisson fixed effects (FE) , panel population-averaged Poisson, negative binomial random effects (RE), negative binomial fixed effects (FE) (Cameron & Trivedi, 2010). These analyze the pattern of sign and significance to ascertain if it remained constant. For each model that corresponds to a slightly different dataset, I computed α to check for the presence of overdispersion and decide which model was most suitable for the hypotheses testing. The results were all consistent with α positive and significant, suggesting the use of negative binomial estimation. For each model, I also considered the Hausman Test to check if it was better to use the negative binomial fixed effect instead of the random effect. To be exhaustive, I recorded it near each table. For different models (and underlying different datasets), the more suited model can change; therefore, I included all possible different statistical specifications for each model (Table from 1.10 to 1.15 in the Appendix to chapter 5), and not just the summary tables, 1.8 and 1.9, comparing the negative binomial random effects results (RE), chosen for the main model, in the different models computed for robustness check. In any case, in all models, the results seem consistent using different statistical specifications.

Sensitivity to construct measurement was tested examining an alternative measure for the centrality construct (results in Table 1.8, column 3; 1.12; 1.13). I re-estimate the model, replacing the measure of variable *Centrality S1-S2* with a different measure than to the one in the main model. The variable is measured by *Efficiency S = 2 step reach / 1 step reach.* In the original model, the 2 step reach was computed including all the nodes at path distance two, irrespective of a simultaneous presence of a direct tie between the focal buyer and the node at distance two (the node in the 2 step reach can be reachable by the focal buyer in one step and in two step simultaneously). On the contrary, this alternative measure was computed including just the nodes that were exactly at path distance of two from the focal buyer, implying that if the nodes were at distance two from the focal buyer but were also connected to it directly they were excluded from the computation. The first measure of the main model is more consistent with the hypotheses formulation: The supplier's centrality among suppliers should include all the suppliers and not just those outside the ego network of the focal buyer; this would provide a partial definition of *centrality*. However, this check was done for two main reasons: first, to ensure that the measure was not mixing two effects - namely, the supplier's centrality and the density in the ego network of the buyers - since higher coordination in the ego network can provide benefit for the implementation of the innovative ideas. Moreover, since a structural holes variable is also included in the main model, I wanted to ensure that I was not introducing harmful duplications in the model. Second, this measure stresses the role of the contacts outside the ego network so that the supplier being central among them is spanning a hole between the focal buyer and the supplier at path distance of two. I wanted to isolate the impact of the external environment and the role of gatekeeper of the supplier. The results show a similar pattern in signs and significance.

Sensitivity to sampling choices was tested running the regression using a sample different from the main model (results are in Table 1.8 column 2; 1.10;1.11). In the main model, I excluded all motor vehicle companies having no operating activities in the United States on the basis of two main motivation: US suppliers in that case would be not representative of the total number of suppliers connected to the focal buyer, and the social exchange would be lower due to low level of proximity. I ran the regression again with the total sample to be consistent with the original source of data, the ELM guide, and to check that my two assumptions were not incorrect and resulting in an eventual bias in the estimation. The results maintain essentially the same pattern of signs and significance.

I ran the regression with both sensitivities analyses simultaneusly (sampling choices and construct measurement). Results are in Table 1.8, column 4 and 1.14; 1.15.

Finally, the correction for multicollinearity between the key variables and the interaction terms has been carried out by mean-deviating the variables, which are components of the interaction, recomputing the interaction, and running the regression again. The results are consistent with those of the main model, allowing it to reject the presence of problems of multicollinearity in the hypotheses testing (results in Table 1.8 column 5; 1.9 column 5).

In sum, the overall findings provide evidence that the model is robust to alternative specifications.

Table 1.6 - Model 1a) - Panel Negative Binomial Re - Copatenting=1.0

Variable				
Centrality S1-S2		0,045**	0,072***	0,445**
		(0,016)	(0,021)	(0,144)
Tie strength FB-S1				0,337
				(0,820)
Centrality S1-S2 * Tie strength FB-S1				-0,343**
				(0,128)
Centrality S1-B2			-0,166*	-1,526***
			(0,076)	(0,419)
Relative tie strength FB-S1/S1-B2				-0,184
				(2,003)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2				1,332***
				(0,387)
Constant	-3,713	-3,158	-6,684*	-1,393
	(2,462)	(2,382)	(2,713)	(1,847)
SH efficiency	4,637°	3,728	7,144**	1,701
	(2,578)	(2,480)	(2,787)	(1,213)
S1	-0,002°	-0,002	-0,002*	-0,002°
	(0,001)	(0,001)	(0,001)	(0,001)
ROA	2,131**	1,842*	2,068**	1,614*
	(0,817)	(0,813)	(0,797)	(0,816)
R&D Intensity	3,384	6,386	5,059	2,420
	(6,632)	(6,496)	(5,597)	(5,971)
Current ratio	-0,460*	-0,521*	-0,349	-0,321
	(0,197)	(0,204)	(0,224)	(0,229)
Debt to equity	-0,011	-0,007	-0,006	-0,005
	(0,010)	(0,009)	(0,009)	(0,009)
Emp	-7,9e-04	-0,001	-8,7e-04	-8,3e-04
	(8,6e-04)	(8,7e-04)	(8,8e-04)	(8,5e-04)
Patents s1	2,6e-04***	2,7e-04***	2,7e-04***	2,7e-04***
	(3,1e-05)	(3,1e-05)	(2,9e-05)	(3,0e-05)
Supply ties FB-B	-0,003	-0,002	-0,005	-0,005
	(0,013)	(0,012)	(0,012)	(0,012)
Horizontal ties FB-B	-0,199***	-0,224***	-0,217***	-0,230***
	(0,038)	(0,035)	(0,031)	(0,032)
Presample patents	0,001**	0,001***	0,001***	0,001***
	(4,6e-04)	(4,0e-04)	(3,4e-04)	(3,7e-04)
N, obs	156	156	156	156
Log Likelihood	-661,388	-658,370	-655,743	-650,150
Chi Sq/df		6,030/1*	5,250/1*	11,190/4*
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis				

Table 1.7 - Model 1a) - Full Model - Copatenting=1.0

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,005**	0,746***	0,748***	0,993*	0,513***	0,445**
	(0,367)	(0,053)	(0,053)	(0,404)	(0,157)	(0,144)
Tie strength FB-S1	-0,611	1,195°	1,264*	-0,086	-0,105	0,337
	(0,876)	(0,631)	(0,620)	(0,304)	(0,845)	(0,820)
Centrality S1-S2 * Tie strength FB-S1	-0,816*	-0,669***	-0,671***	-0,871*	-0,426**	-0,343**
	(0,330)	(0,050)	(0,049)	(0,375)	(0,142)	(0,128)
Centrality S1-B2	-2,540*	-2,158***	-2,172***	-2,953**	-1,704***	-1,526***
	(1,098)	(0,172)	(0,171)	(1,072)	(0,480)	(0,419)
Relative tie strength FB-S1/S1-B2	5,411	-2,501***	-2,535***	-0,238	-0,117	-0,184
	(4,238)	(0,642)	(0,637)	(4,005)	(2,085)	(2,003)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,144*	2,125***	2,136***	2,726**	1,567***	1,332***
	(0,994)	(0,164)	(0162)	(0,970)	(0,455)	(0,387)
Constant	-6,471		4,482***	1,555	-0,364	-1,393
	(4,918)		(0,666)	(3,610)	(2,035)	(1,847)
SH efficiency	3,953	-0,215	-0,188	1,947	0,936	1,701
	(3,810)	(0,419)	(0,418)	(2,232)	(1,380)	(1,213)
S1	-0,001	0,005***	0,004***	-0,001	1,5e-04	-0,002°
	(0,001)	(7,1e-04)	(6,9e-04)	(0,001)	(0,001)	(0,001)
ROA	5,639*	2,173***	2,146***	3,031*	-0,535	1,614*
	(2,584)	(0,294)	(0,293)	1,461)	(1,187)	(0,816)
R&D Intensity	17,918°	0,415	0,624	7,654	0,649	2,420
	(10,098)	(1,569)	(1,563)	(6,144)	(7,371)	(5,971)
Current ratio	0,122	-0,096	-0,106°	-0,016	-0,011	-0,321
	(0,261)	(0,064)	(0,064)	(0,207)	(0,241)	(0,229)
Debt to equity	-0,010	-0,016***	-0,016***	-0,011°	-0,292*	-0,005
	(0,014)	(0,004)	(0,004)	(0,006)	(0,014)	(0,009)
Emp	-0,001	-0,002***	-0,002***	-4,0e-04	2,3e-04	-8,3e-04
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,5e-04)
Patents s1	2,2e-04**	2,5e-04***	2,5e-04***	2,4e-04***	2,5e-04***	2,7e-04***
	(7,2e-04)	(8,4e-06)	(8,3e-06)	(4,5e-05)	(3,9e-05)	(3,0e-05)
Supply ties FB-B	0,012	-0,022***	-0,021***	0,010	-0,007	-0,005
	(0,028)	(0,005)	(0,005)	(0,018)	(0,028)	(0,012)
Horizontal ties FB-B	-0,042	-0,217***	-0,218***	-0,132**	-0,121*	-0,230***
	(0,051)	(0,009)	(0,009)	(0,047)	(0,048)	(0,032)
Presample patents	8,6e-04***		0,001*	8,3e-04***		0,001***
	(1,0e-04)		(5,1e-04)	(1,2e-04)		(3,7e-04)
N, obs	156	145	156	156	145	156
Log Likelihood	-6380,293	-1084,305	-1311,328		-420,768	-650,150

° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis

$\alpha = 2{,}017$ Hausman Prob>chi2 = 1.0

Table 1.8 - Models 1-5 - Robustness Checks

	1 Main	2 Sampling	3 Construct Measurement	4 Sampling and Construct Measurement	5 Multicollinearity check
Variable					
Centrality S1-S2	0,446** (0,144)	0,463** (0,148)	0,378** (0,145)	0,401** (0,148)	0,093*** (0,024)
Tie strength FB-S1	0,233 (0,829)	0,140 (0,805)	0,120 (0,832)	0,010 (0,808)	-1,904° (1,073)
Centrality S1-S2 * Tie strength FB-S1	-0,342** (0,129)	-0,358** (0,131)	-0,275* (0,125)	-0,294* (0,128)	-0,343** (0,129)
Centrality S1-B2	-1,494*** (0,422)	-1,562*** (0,437)	-1,572*** (0,351)	-1,635*** (0,364)	-0,184* (0,083)
Relative tie strength FB-S1/S1-B2	0,017 2,003)	0,064 (1,992)	-1,134 (2,008)	-1,024 (1,992)	2,464 (1,986)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	1,303*** (0,389)	1,357*** (0,402)	1,316*** (0,329)	1,364*** (0,340)	1,305*** (0,389)
Constant	-1,398 (1,858)	-1,394 (1,846)	-1,229 (1,811)	-1,227 (1,804)	-0,907 (1,287)
SH efficiency	1,602 (1,219)	1,690 (1,190)	2,529* (1,258)	2,554* (1,242)	1,603 (1,218)
S1	-0,002 (0,001)	-0,002 (0,001)	-0,002° (0,001)	-0,002° (0,001)	-0,002 (0,001)
ROA	1,499° (0,848)	1,522° (0,846)	1,818* (0,841)	1,822* (0,837)	1,499° (0,847)
R&D Intensity	3,046 (6,211)	2,886 (6,202)	3,961 (5,562)	3,825 (5,533)	3,023 (6,208)
Current ratio	-0,319 (0,230)	-0,320 (0,231)	-0,216 (0,217)	-0,208 (0,217)	-0,319 (0,230)
Debt to equity	-0,005 (0,009)	-0,005 (0,009)	-0,004 (0,009)	-0,004 (0,009)	-0,005 (0,009)
Emp	-0,001 (9,0e-04)	-0,001 (8,9e-04)	-7,4e-04 (8,8e-04)	-6,9e-04 (8,8e-04)	-0,001 (0,001)
Patents s1	2,8e-04*** (3,3e-05)	2,8e-04*** (3,3e-05)	2,7e-04*** (3,2e-05)	2,8e-04*** (3,2e-05)	2,8e-04*** (3,3e-05)
Supply ties FB-B	-0,005 (0,013)	-0,006 (0,013)	-0,009 (0,011)	-0,012 (0,011)	-0,005 (0,013)
Horizontal ties FB-B	-0,232*** (0,036)	-0,229*** (0,036)	-0,218*** (0,037)	-0,216*** (0,037)	-0,232*** (0,036)
Presample patents	0,001*** (3,9e-04)	0,001*** (3,9e04)	0,001*** (3,9e-04)	0,001*** (3,9e-04)	0,001*** (3,9e-04)
N, obs	156	156	181	181	156
Log Likelihood	-646,142	-645,945	-696,204	-695,711	-646,128
° p<0,1 ; p* p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis					

Table 1.9 - Models 1a)-5 - Robustness Checks - Copatenting = 1.0

	1 Main	2 Sampling	3 Construct Measurement	4 Sampling and Construct Measurement	5 Multicollinearity check
Variable					
Centrality S1-S2	0,445**	0,461**	0,372**	0,394**	0,092***
	(0,144)	(0,147)	(0,143)	(0,146)	-0,024
Tie strength FB-S1	0,337	0,252	0,206	0,106	-1,801°
	(0,820)	(0,797)	(0,819)	(0,797)	(1,068)
Centrality S1-S2 * Tie strength FB-S1	-0,343**	-0,358**	-0,271*	-0,288*	-0,343**
	(0,128)	(0,131)	(0,123)	(0,126)	(0,128)
Centrality S1-B2	-1,526***	-1,593***	-1,565***	-1,627***	-0,186*
	(0,419)	(0,434)	(0,346)	(0,359)	(0,082)
Relative tie strength FB-S1/S1-B2	-0,184	-0,151	-1,277	-1,181	2,317
	(2,003)	(1,992)	(1,985)	(1,968)	(1,985)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	1,332***	1,386***	2,621*	1,361***	1,334***
	(0,387)	(0,399)	(1,250)	(0,335)	(0,387)
Constant	-1,393	-1,387	-1,232	-1,227	-1,008
	(1,847)	(1,836)	(1,791)	(1,784)	(1,278)
SH efficiency	1,701	1,794	2,621*	2,649*	1,702
	(1,213)	(1,184)	(1,250)	(1,233)	(1,213)
S1	-0,002°	-0,002°	-0,003*	-0,003*	-0,002°
	(0,001)	(0,001)	(0,001)	(0,001)	(0,001)
ROA	1,614*	1,636*	1,872*	1,880*	1,614*
	(0,816)	(0,815)	(0,807)	(0,804)	(0,815)
R&D Intensity	2,420	2,267	3,470	3,324	2,394
	(5,971)	(5,974)	(5,339)	(5,324)	(5,696)
Current ratio	-0,321	-0,324	-0,235	-0,228	-0,322
	(0,229)	(0,229)	(0,216)	(0,217)	(0,229)
Debt to equity	-0,005	-0,005	-0,004	-0,004	-0,005
	(0,009)	(0,009)	(0,009)	(0,009)	(0,009)
Emp	-8,3e-04	-7,8e-04	-4,4e-04	-4,0e-04	-8,0e-04
	(8,5e-04)	(8,5e-04)	(8,2e-04)	(8,2e-04)	(8,5e-04)
Patents s1	2,7e-04***	2,7e-04***	2,7e-04***	2,7e-04***	2,7e-04***
	(3,0e-05)	(2,9e-05)	(2,9e-05)	(2,9e-05)	(3,0e-05)
Supply ties FB-B	-0,005	-0,006	-0,009	-0,010	-0,005
	(0,012)	(0,011)	(0,010)	(0,010)	(0,011)
Horizontal ties FB-B	-0,230***	-0,227***	-0,221***	-0,218***	-0,230***
	(0,032)	(0,032)	(0,032)	(0,032)	(0,033)
Presample patents	0,001***	0,001***	0,002***	0,002***	0,001***
	(3,7e-04)	(3,6e-04)	(3,6e-04)	(3,6e-04)	(3,7e-04)
N, obs	156	156	181	181	156
Log Likelihood	-650,150	-649,984	-701,969	-701,517	-650,135

° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis

APPENDIX TO CHAPTER 5

Table 1.10 - Model 2 - Full Model - Sensitivity to sampling choices

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,138**	0,774***	0,783***	1,144**	0,342*	0,378**
	(0,386)	(0,057)	(0,056)	(0,422)	(0,152)	(0,145)
Tie strength FB-S1	-0,824	1,934**	2,011**	-0,167	-0,322	0,120
	(1,001)	(0,709)	(0,695)	(0,449)	(0,870)	(0,832)
Centrality S1-S2 *	-0,933**	-0,691***	-0,698***	-0,998*	-0,264*	-0,275*
Tie strength FB-S1	(0,345)	(0,053)	(0,053)	(0,395)	(0,134)	(0,125)
Centrality S1-B2	-2,847**	-2,111***	-2,151***	-3,086*	-1,307***	-1,572***
	(1,072)	(0,171)	(0,169)	(1,353)	(0,400)	(0,351)
Relative tie strength	5,398	-3,434***	-3,475***	-0,804	-1,301	-1,134
FB-S1/S1-B2	(4,020)	(0,675)	(0,669)	(4,693)	(2,182)	(2,008)
Centrality S1-B2 *	2,437*	2,059***	2,092***	2,806*	1,184**	1,316***
Relative tie strength	(0,978)	(0,161)	(0,159)	(1,336)	(0,377)	(0,329)
FB-S1/S1-B2						
Constant	-7,756		4,018***	-0,514	-0,071	-1,229
	(5,372)		(0,659)	(7,820)	(2,069)	(1,811)
SH efficiency	5,319	0,301	0,361	4,457	1,873	2,529*
	(4,608)	(0,429)	(0,427)	(5,629)	(1,408)	(1,258)
S1	-7,6e-04	0,004***	0,004***	-0,001	2,2e-04	-0,002°
	(0,001)	(7,1e-04)	(6,9e-04)	(0,001)	(0,001)	(0,001)
ROA	5,469*	1,784***	1,757***	2,835*	-0,582	1,818*
	(2,557)	(0,296)	(0,295)	(1,327)	(1,157)	(0,841)
R&D Intensity	18,063°	2,082	2,238	8,657	3,074	3,961
	(9,623)	(1,557)	(1,550)	(6,053)	(7,201)	(5,562)
Current ratio	0,200	-0,229***	-0,238***	0,008	-0,006	-0,216
	(0,243)	(0,068)	(0,068)	(0,217)	(0,283)	(0,217)
Debt to equity	-0,009	-0,015***	-0,016***	-0,013°	-0,029*	-0,004
	(0,014)	(0,004)	(0,004)	(0,007)	(0,014)	(0,009)
Emp	-0,001	-0,003***	-0,002***	-7,2e-04	2,1e-04	-7,4e-04
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,8e-04)
Patents s1	2,4e-04***	2,7e-04***	2,7e-04***	2,6e-04***	2,7e-04***	2,7e-04***
	(7,5e-05)	(8,8e-06)	(8,7e-06)	(4,7e-05)	(4,1e-05)	(3,2e-05)
Supply ties FB-B	-0,011	-0,019***	-0,019***	-0,002	-0,017	-0,009
	(0,023)	(0,004)	(0,004)	(0,014)	(0,023)	(0,011)
Horizontal ties FB-B	-0,068	-0,229***	-0,229***	-0,145**	-0,122**	-0,218***
	(0,057)	(0,009)	(0,009)	(0,046)	(0,046)	(0,037)
Presample patents	9,2e-04***		0,001**	9,0e-04***		0,001***
	(1,0e-04)		(5,5e-04)	(1,3e-04)		(3,9e-04)
N, obs	181	166	181	181	166	181
Log Likelihood	-6545,205	-1093,903	-1344,335		-445,992	-696,204
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis						

$\alpha = 2{,}177$ Hausman Prob>chi2 = na> FE

Table 1.11 - Model 2a) - Full Model - Sensitivity to sampling choices - Copatenting=1.0

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,144**	0,743***	0,752***	1,116**	0,339*	0,372**
	(0,384)	(0,055)	(0,055)	(0,413)	(0,152)	(0,143)
Tie strength FB-S1	-0,859	1,753**	1,833**	-0,158	-0,139	0,206
	(1,002)	(0,670)	(0,659)	(0,444)	(0,841)	(0,819)
Centrality S1-S2 * Tie strength FB-S1	-0,938**	-0,665***	-0,672***	-0,969*	-0,262*	-0,271*
	(0,342)	(0,052)	(0,051)	(0,388)	(0,133)	(0,123)
Centrality S1-B2	-2,826**	-2,053***	-2,093***	-3,006*	-1,317***	-1,565***
	(1,050)	(0,166)	(0,165)	(1,248)	(0,396)	(0,346)
Relative tie strength FB-S1/S1-B2	5,816	-3,404***	-3,445***	-0,345	-1,483	-1,277
	(4,063)	(0,654)	(0,649)	(4,555)	(2,146)	(1,985)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,409*	2,016***	2,048***	2,719*	1,196***	2,621*
	(0,956)	(0,157)	(0,155)	(1,232)	(0,374)	(1,250)
Constant	-8,254		3,806***	-1,218	-0,201	-1,232
	(5,572)		(0,651)	(7,759)	(2,048)	(1,791)
SH efficiency	5,454	0,516	0,572	4,739	1,984	2,621*
	(4,798)	(0,420)	(0,418)	(5,713)	(1,406)	(1,250)
S1	-8,8e-04	0,004***	0,004***	-0,001	1,2e-04	-0,003*
	(0,001)	(7,0e-04)	(6,8e-04)	(0,001)	(0,001)	(0,001)
ROA	5,525*	2,095***	2,072***	3,199*	-0,403	1,872*
	(2,533)	(0,292)	(0,291)	(1,413)	(1,153)	(0,807)
R&D Intensity	17,057°	0,509	0,665	7,750	3,382	3,470
	(9,706)	(1,525)	(1,518)	(6,155)	(7,213)	(5,339)
Current ratio	0,213	-0,087	-0,097	0,020	-0,007	-0,235
	(0,247)	(0,064)	(0,064)	(0,220)	(0,239)	(0,216)
Debt to equity	-0,013	-0,016***	-0,017***	-0,014*	-0,030*	-0,004
	(0,013)	(0,004)	(0,004)	(0,007)	(0,014)	(0,009)
Emp	-0,001	-0,002***	-0,002***	-4,0e-04	4,3e-04	-4,4e-04
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,2e-04)
Patents s1	2,4e-04***	2,5e-04***	2,5e-04***	2,5e-04***	2,6e-04***	2,7e-04***
	(7,0e-05)	(8,3e-06)	(8,3e-06)	(4,5e-05)	(4,0e-05)	(2,9e-05)
Supply ties FB-B	-0,007	-0,022***	-0,021***	1,0e-04	-0,018	-0,009
	(0,021)	(0,004)	(0,004)	(0,014)	(0,023)	(0,010)
Horizontal ties FB-B	-0,053	-0,218***	-0,218***	-0,131**	-0,121**	-0,221***
	(0,053)	(0,009)	(0,009)	(0,047)	(0,046)	(0,032)
Presample patents	8,9e-04***		0,001*	8,7e-04***		0,002***
	(1,0e-04)		(5,4e-04)	(1,3e-04)		(3,6e-04)
N, obs	181	166	181	181	166	181
Log Likelihood	-6720,748	-1125,612	-1378,183		-450,749	-701,969
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis						

α = 2,180 Hausman Prob>chi2 = 0.7584

Table 1.12 - Model 3 - Full Model - Sensitivity to construct measurement

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,038**	0,721***	0,725***	1,025*	0,508***	0,463**
	(0,376)	(0,052)	(0,052)	(0,421)	(0,159)	(0,148)
Tie strength FB-S1	-0,800	0,115	0,223	-0,287	-0,441	0,140
	(0,847)	(0,558)	(0,544)	(0,322)	(0,842)	(0,805)
Centrality S1-S2 * Tie strength FB-S1	-0,845*	-0,640***	-0,643***	-0,899*	-0,420**	-0,358**
	(0,339)	(0,048)	(0,048)	(0,391)	(0,143)	(0,131)
Centrality S1-B2	-2,697*	-2,059***	-2,081***	-3,097**	-1,665***	-1,562***
	(1,150)	(0,171)	(0,169)	(1,167)	(0,487)	(0,437)
Relative tie strength FB-S1/S1-B2	5,163	-1,630**	-1,694**	-0,544	0,234	0,064
	(4,239)	(0,617)	(0,611)	(4,072)	(2,087)	(1,992)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,277*	2,001***	2,018***	2,859**	1,524***	1,357***
	(1,043)	(0,160)	(0,159)	(1,053)	(0,459)	(0,402)
Constant	-5,672		4,649***	2,035	-0,426	-1,394
	(4,386)		(0,667)	(3,343)	(2,027)	(1,846)
SH efficiency	3,643	0,013	0,039	2,007	1,041	1,690
	(3,210)	(0,419)	(0,418)	(1,867)	(1,351)	(1,190)
S1	-9,1e-04	0,005***	0,004***	-0,001	3,6e-04	-0,002
	(0,001)	(7,2e-04)	(7,0e-04)	(0,001)	(0,001)	(0,001)
ROA	5,543*	1,925***	1,892***	2,646°	-0,681	1,522°
	(2,590)	(0,297)	(0,297)	(1,378)	(1,183)	(0,846)
R&D Intensity	18,868°	1,373	1,609	8,350	0,624	2,886
	(9,952)	(1,600	(1,594)	(5,947)	(7,365)	(6,202)
Current ratio	0,111	-0,213**	-0,223***	-0,036	-0,015	-0,320
	(0,257)	(0,069)	(0,068)	(0,204)	(0,244)	(0,231)
Debt to equity	-0,007	-0,015***	-0,015***	-0,010	-0,029*	-0,005
	(0,015)	(0,004)	(0,004)	(0,006)	(0,014)	(0,009)
Emp	-0,001	-0,003***	-0,002***	-7,6e-04	-1,4e-04	-0,001
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,9e-04)
Patents s1	2,2e-04**	2,7e-04***	2,7e-04***	2,5e-04***	2,6e-04***	2,8e-04***
	(7,7e-05)	(8,9e-06)	(8,8e-06)	(4,7e-05)	(4,1e-05)	(3,3e-05)
Supply ties FB-B	0,005	-0,021***	-0,019***	0,006	-0,008	-0,006
	(0,029)	(0,004)	(0,005)	(0,019)	(0,028)	(0,013)
Horizontal ties FB-B	-0,053	-0,219***	-0,220***	-0,145***	-0,123*	-0,229***
	(0,055)	(0,009)	(0,009)	(0,045)	(0,049)	(0,036)
Presample patents	8,9e-04***		0,001*	8,7e-04***		0,001***
	(1,0e-04)		(5,2e-04)	(1,1e-04)		(3,9e04)
N, obs	156	145	156	156	145	156
Log Likelihood	-6165,302	-1057,734	-1283,353		-417,324	-645,945

° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis

α = 2,000 Hausman Prob>chi2 = 0.9982

Table 1.13 - Model 3a) - Full Model - Sensitivity to construct measurement - Copatenting=1.0

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,054**	0,711***	0,714***	1,032*	0,518***	0,461**
	(0,375)	(0,051)	(0,050)	(0,417)	(0,159)	(0,147)
Tie strength FB-S1	-0,755	0,147	0,237	-0,267	-0,226	0,252
	(0,855)	(0,508)	(0,505)	(0,330)	(0,818)	(0,797)
Centrality S1-S2 * Tie strength FB-S1	-0,859*	-0,633***	-0,636***	-0,904*	-0,431**	-0,358**
	(0,338)	(0,047)	(0,047)	(0,387)	(0,144)	(0,131)
Centrality S1-B2	-2,712*	-2,069***	-2,086***	-3,097**	-1,736***	-1,593***
	(1,131)	(0,168)	(0,167)	(1,123)	(0,489)	(0,434)
Relative tie strength FB-S1/S1-B2	5,463	-1,811**	-1,859**	-0,174	-0,854	-0,151
	(4,267)	(0,597)	(0,593)	(4,102)	(2,080)	(1,992)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,287*	2,021***	2,035***	2,847**	1,590***	1,386***
	(1,023)	(0,157)	(0,156)	(1,011)	(0,462)	(0,399)
Constant	-6,085		4,421***	1,517	-0,464	-1,387
	(4,494)		(0,660)	(3,491)	(2,024)	(1,836)
SH efficiency	3,722	0,234	0,259	2,152	1,139	1,794
	(3,305)	(0,409)	(0,408)	(1,920)	(1,352)	(1,184)
S1	-0,001	0,005***	0,005***	-0,001	1,4e-04	-0,002°
	(0,001)	(7,1e-04)	(6,9e-04)	(0,001)	(0,001)	(0,001)
ROA	5,603*	2,233***	2,205***	3,079*	-0,537	1,636*
	(2,580)	(0,294)	(0,293)	(1,487)	(1,187)	(0,815)
R&D Intensity	17,871°	-0,159	0,066	7,609	0,735	2,267
	(10,072)	(1,570)	(1,564)	(6,132)	(7,362)	(5,974)
Current ratio	0,127	-0,071	-0,081	-0,017	0,003	-0,324
	(0,260)	(0,064)	(0,064)	(0,208)	(0,243)	(0,229)
Debt to equity	-0,009	-0,015***	-0,016***	-0,011°	-0,029*	-0,005
	(0,014)	(0,004)	(0,004)	(0,006)	(0,014)	(0,009)
Emp	-9,2e-04	-0,002***	-0,002***	-4,3e-04	2,5e-04	-7,8e-04
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,5e-04)
Patents s1	2,2e-04**	2,5e-04***	2,6e-04***	2,4e-04***	2,5e-04***	2,7e-04***
	(7,2e-05)	(8,4e-06)	(8,3e-06)	(4,5e-05)	(3,9e-05)	(2,9e-05)
Supply ties FB-B	0,010	-0,024***	-0,022***	0,009	-0,008	-0,006
	(0,028)	(0,005)	(0,004)	(0,018)	(0,028)	(0,011)
Horizontal ties FB-B	-0,038	-0,209***	-0,210***	-0,128**	-0,119*	-0,227***
	(0,051)	(0,009)	(0,009)	(0,046)	(0,048)	(0,032)
Presample patents	8,7e-04***		0,001*	8,3e-04***		0,001***
	(1,0e-04)		(5,1e-04)	(1,1e-04)		(3,6e-04)
N, obs	156	145	156	156	145	156
Log Likelihood	-6329,512	-1086,843	-1314,164		-420,656	-649,984
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis						

α = 2,004 Hausman Prob>chi2 = 0.9998

Table 1.14 - Model 4 - Full Model - Sensitivity to sampling choices and construct measurement

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,189**	0,728***	0,739***	1,291**	0,350*	0,401**
	(0,396)	(0,055)	(0,054)	(0,484)	(0,156)	(0,148)
Tie strength FB-S1	-1,109	0,545	0,663	-0,449	-0,464	0,010
	(0,965)	(0,586)	(0,573)	(0,445)	(0,846)	(0,808)
Centrality S1-S2 * Tie strength FB-S1	-0,977**	-0,642***	-0,652***	-1,143**	-0,271*	-0,294*
	(0,354)	(0,050)	(0,049)	(0,445)	(0,137)	(0,128)
Centrality S1-B2	-3,007**	-1,991***	-2,039***	-3,895**	-1,347***	-1,635***
	(1,110)	(0,165)	(0,164)	(1,356)	(0,411)	(0,364)
Relative tie strength FB-S1/S1-B2	5,607	-2,521***	-2,589***	-1,893	-1,196	-1,024
	(4,048)	(0,625)	(0,619)	(4,660)	(2,182)	(1,992)
Centrality S1-B2 * Relative tie strength FB-S1/S1-B2	2,564*	1,921***	1,962***	3,612**	1,213**	1,364***
	(1,006)	(0,153)	(0,152)	(1,255)	(0,386)	(0,340)
Constant	-7,312		4,183***	2,600	-0,108	-1,227
	(4,691)		(0,651)	(3,360)	(2,074)	(1,804)
SH efficiency	5,019	0,660	0,725°	2,723	1,929	2,554*
	(3,877)	(0,426)	(0,423)	(1,686)	(1,391)	(1,242)
S1	-7,7e-04	0,004***	0,004***	-0,001	1,6e-04	-0,002°
	(0,001)	(7,2e-04)	(7,0e-04)	(0,001)	(0,001)	(0,001)
ROA	5,389*	1,761***	1,734***	2,797*	-0,642	1,822*
	(2,526)	(0,295)	(0,295)	(1,344)	(1,140)	(0,837)
R&D Intensity	18,048°	2,385	2,562°	8,348	2,711	3,825
	(9,636)	(1,548)	(1,542)	(5,967)	(7,143)	(5,533)
Current ratio	0,204	-0,231***	-0,241***	0,010	0,029	-0,208
	(0,244)	(0,068)	(0,068)	(0,218)	(0,239)	(0,217)
Debt to equity	-0,009	-0,014***	-0,015***	-0,013°	-0,029*	-0,004
	(0,014)	(0,004)	(0,004)	(0,007)	(0,013)	(0,009)
Emp	-0,001	-0,002***	-0,002***	-7,7e-04	4,5e-04	-6,9e-04
	(0,001)	(3,5e-04)	(3,5e-04)	(0,001)	(0,001)	(8,8e-04)
Patents s1	2,4e-04***	2,7e-04***	2,7e-04***	2,6e-04***	2,7e-04***	2,8e-04***
	(7,6e-05)	(8,8e-06)	(8,7e-06)	(4,7e-05)	(4,1e-05)	(3,2e-05)
Supply ties FB-B	-0,013	-0,015***	-0,014***	-0,002	-0,025	-0,012
	(0,023)	(0,004)	(0,004)	(0,015)	(0,022)	(0,011)
Horizontal ties FB-B	-0,063	-0,223***	-0,223***	-0,146***	-0,114*	-0,216***
	(0,057)	(0,009)	(0,009)	(0,045)	(0,047)	(0,037)
Presample patents	9,3e-04***		0,001**	9,3e-04***		0,001***
	(1,0e-04)		(5,5e-04)	(1,3e-04)		(3,9e-04)
N, obs	181	166	181	181	166	181
Log Likelihood	-6473,840	-1103,681	-1354,137		-445,493	-695,711
° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis						

$\alpha = 2,160$ Hausman Prob>chi2 = na>FE

Table 1.15 - Model 4a) - Full Model - Sensitivity to sampling choices and construct measurement - Copatenting = 1.0

	Pooled Poisson	Panel Poisson Fe	Panel Poisson Re	Panel Poisson Population-averaged	Panel Negative Binomial Fe	Panel Negative Binomial Re
Variable						
Centrality S1-S2	1,196**	0,700***	0,711***	1,171**	0,348*	0,394**
	(0,392)	(0,053)	(0,052)	(0,428)	(0,155)	(0,146)
Tie strength FB-S1	-1,062	0,457	0,561	-0,425	-0,276	0,106
	(0,964)	(0,537)	(0,528)	(0,472)	(0,816)	(0,797)
Centrality S1-S2 *	-0,983**	-0,619***	-0,628***	-1,019*	-0,271*	-0,288*
Tie strength FB-S1	(0,349)	(0,049)	(0,048)	(0,399)	(0,136)	(0,126)
Centrality S1-B2	-2,990**	-1,941***	-1,987***	-3,241**	-1,360***	-1,627***
	(1,086)	(0,161)	(0,160)	(1,233)	(0,408)	(0,359)
Relative tie strength	5,931	-2,556***	-2,612***	-0,367	-1,385	-1,181
FB-S1/S1-B2	(4,068)	(0,601)	(0,598)	(4,553)	(2,144)	(1,968)
Centrality S1-B2 *	2,543*	1,886***	1,924***	2,929*	1,228***	1,361***
Relative tie strength	(0,982)	(0,149)	(0,148)	(1,187)	(0,383)	(0,335)
FB-S1/S1-B2						
Constant	-7,772		3,951***	-0,802	-0,239	-1,227
	(4,849)		(0,642)	(6,483)	(2,053)	(1,784)
SH efficiency	5,126	0,865*	0,925*	4,671	2,043	2,649*
	(4,031)	(0,416)	(0,414)	(4,731)	(1,389)	(1,233)
S1	-8,8e-04	0,004***	0,004***	-0,001	3,6e-05	-0,003*
	(0,001)	(7,1e-04)	(6,6e-04)	(0,001)	(0,001)	(0,001)
ROA	5,453*	2,051***	2,028***	3,214*	-0,468	1,880*
	(2,498)	(0,292)	(0,290)	(1,415)	(1,137)	(0,804)
R&D Intensity	17,018°	0,712	0,876	7,658	3,012	3,324
	(9,708)	(1,511)	(1,505)	(6,169)	(7,156)	(5,324)
Current ratio	0,217	-0,088	-0,097	0,018	0,029*	-0,228
	(0,248)	(0,064)	(0,063)	(0,226)	(0,241)	(0,217)
Debt to equity	-0,012	-0,014***	-0,015***	-0,013*	-0,029	-0,004
	(0,013)	(0,004)	(0,004)	(0,007)	(0,013)	(0,009)
Emp	-0,001	-0,002***	-0,002***	-3,9e-04	6,7e-04	-4,0e-04
	(0,001)	(3,5e-04)	(3,4e-04)	(0,001)	(0,001)	(8,2e-04)
Patents s1	2,4e-04***	2,5e-04***	2,5e-04***	2,5e-04***	2,6e-04***	2,7e-04***
	(7,0e-05)	(8,3e-06)	(8,3e-06)	(4,5e-05)	(4,0e-05)	(2,9e-05)
Supply ties FB-B	-0,009	-0,019***	-0,018***	-9,2e-04	-0,026	-0,010
	(0,022)	(0,004)	(0,004)	(0,015)	(0,023)	(0,010)
Horizontal ties FB-B	-0,049	-0,212***	-0,212***	-0,129**	.0,113*	-0,218***
	(0,053)	(0,009)	(0,009)	(0,046)	(0,046)	(0,032)
Presample patents	9,0e-04***		0,001*	8,7e-04***		0,002***
	(1,0e-04)		(5,4e-04)	(1,2e-04)		(3,6e-04)
N, obs	181	166	181	181	166	181
Log Likelihood	-6650,181	-1134,586	-1387,239		-450,264	-701,517

° p<0,1 ; * p<0,05 ; ** p<0,01; *** p<0,001. Standard errors are in parenthesis

α = 2,162 Hausman Prob>chi2 = 0.9935

DISCUSSION AND CONCLUSIONS

This section will highlight some of the contributions of the thesis to theory and managerial practice and provide recommendations for further research. The core theoretical contribution of this thesis is the development of a theoretical framework relating a firm's network of vertical relationships[13] to its innovative performance. Specifically, the research focuses on the assessment of a causal relation between the supplier's network of relationships (with buyers and suppliers) and the buyer's innovation output. In this context, from a social network perspective, I basically proved that ego's innovation is affected by alters' alters in a manner that is contingent on some factors. Depending on the presence of suppliers or other buyers as alters' alters, I distinguished between collaborative and competitive dimensions of a supplier-buyer network, stressing the concept of supplier mediated cooperation/competition. In these two dimensions, the contingencies analyzed have different roles, alternatively positive and negative. The contingencies are the type of nodes involved in indirect ties (with reference to their role in the supply chain) and the type of relationships (arm's length tie or alliance or both) expressed in terms of tie strength. The impact of the strength of the ties was analyzed in the two cases. Therefore, the study analyzed a multiplex network, with multiple types of edges and nodes.

In these respects, this work can enrich under-explored pathways in social network literature in the following ways. First, while prior research mainly focused on the effect of horizontal collaborative relationships on firm innovation, I focused on vertical relationships. Second, while prior research only highlighted the benefits of indirect ties, I maintain that a contingent approach is needed to evaluate the effect of indirect ties, which is not always positive. The commonly acknowledged conclusion that selecting alters with many other partners is a good mechanism to follow was called into question. It turned out that the type of actors involved in indirect ties is the discriminating factor. Third, while the network approach focused mainly on the creation of value through win/win benefits based on exchange and pooling competencies, I also analyzed the dynamics of competition in the network, which were largely underexamined in relation to the innovation output. I tried to enrich one under-explored line of investigation, that which reverses

[13] Where a vertical relation is identified as a relation that involves nodes located at different levels of the supply chain, namely, a buyer and a supplier. It is not the type of tie that determines a vertical tie; it is the type of actors involved in the tie. Therefore, a vertical tie can be either an alliance or supply tie.

the usual logic of social capital and examines the negative consequences of social capital, the so-called "dark side." The buyers indirectly linked through the same supplier compete for the use of innovation that is often exclusive while indirectly cooperating to contribute to building a common knowledge base and the competences of the supplier. Some criteria (network characteristics) were searched to determine ex ante to what extent a focal buyer can benefit from this variable game structure. Fourth, the work contributed to the debate on the trade-off between strong and weak ties, in place among network scholars: The effects of tie strength (depending on the type of tie) on the innovation output was shown to be contingent on the context (e.g., competition for information). In the literature, a contingent approach to assess the effects of structural holes has already been adopted (Ahuja, 2000); less is known about whether, why, and how network architectures that differ in tie strength exert a different impact on the innovative capability of the lead firm in a network (Capaldo, 2007). Finally, by using a multiplex network, the study tried to provide answers to the emerging need in social network analysis to enrich the analyses with more complex modelling constructs. It sets up the grounds for the study of multiplexity.

The theoretical contribution derives from the integration and extension of *network theory, supplier-buyer relationships literature,* and *transaction costs economics*. I also referred to literature on cooperation and competition. I explain the benefits of this integration in the following paragraphs.

First, bridging *network theory* and *supplier-buyer relationship literature* is useful in integrating in a single framework the concepts of *relational embeddedness* and *structural embeddedness* in a context of vertical ties. In fact, while the first stream of research is focused on the system, the overall structure and on the position of the node; the second line of research stresses the dyadic buyer-supplier relationship and the quality of the single relation, which is characterized by trust, commitment, etc. This also implies an extension of the supplier-buyer relationship literature through the introduction of network-level characteristics for supplier selection and the concept of the supplier as a strategic broker through which proprietary knowledge can potentially flow. In fact, in the literature on supplier-buyer ties, innovation output has been traced back to supplier selection and is based on firm-level technical capabilities and supplier dyadic relationship development and adaptation.

In fact to build my theoretical framework, I relied on both a positional and a relational approach. I adopted a positional network approach to postulate two main effects regarding the impact of the supplier's network centrality on the buyer's innovation output. The supplier's centrality in a network of suppliers has a positive impact on the buyer's innovative performance, while supplier's centrality in a network of buyers has a negative influence. This suggested that the effect of centrality in a network was dependent on the type of nodes involved in the indirect ties. Then, I adopted a relational network approach to argue that these two main effects are moderated by the strength of the ties in the direct relationships. The strength of the focal buyer-supply tie negatively moderates the first main effect, while the relative strength of the focal buyer-supplier tie versus supplier-other buyer ties positively moderates the second main effect. In this way, I found support for the strength of weak ties in a collaborative context and for the strength of strong ties in a competitive context, where the actors compete for the information and for the exploitation of the innovation.

Second, the adoption of two perspectives, *network theory*, particularly *social capital theory*, and *transaction cost economics*, and their interplay in the study of supply relationships, provide new insights on the drivers of actors’ payoff focusing both on knowledge sharing and opportunistic threat. The mechanism underlying the aforementioned set of hypotheses is basically the trade-off between benefits from positive knowledge leakage (flow of knowledge from the network to the ego) and opportunistic threats from negative knowledge spillover (flow of knowledge from the ego to the network) in a context of indirect ties. The thesis deepened the understanding of suppliers’ network characteristics, favoring the positive leakiness and positive stickiness for the focal buyer and, consequently, spurring buyers’ innovation output. This is in line with TCE, according to which collaborative efficiency and efficacy is assumed to be achieved on the part of the firm when the firm can limit its partner's opportunistic behavior. The advice is to be suspicious of one’s own partners and of the results of collaborative arrangements.

The combination of the aforementioned perspective implies that the focus in a context of inter-firm relationships is not just to "create the positive" but to "avoid the negative." This is the basic principle underlying the hypotheses that were expressed in the three propositions I presented in Chapter 3 before the hypotheses formulation. First, a supplier's centrality determines the incoming and outgoing knowledge flow between the buyer and the supplier's partners and, hence, affects the buyer's innovation output. Second, a supplier's centrality has a positive effect on the focal buyer's innovation output to the extent that the context determines an increase in positive leakiness and a reduction in negative leakiness for the buyer. This means more available resources and fewer negative spillovers. Third, the strength of the relationships enhances or reduces the effect of a supplier's centrality on the focal buyer's innovation, depending on whether the context requires prevailingly fostering positive leakiness or preventing negative leakiness.

Therefore, the supplier's centrality in the network of suppliers has a positive impact on buyer's innovation because it determines an increase in positive leakage and a reduction in negative spillovers. The supplier's centrality in the network of buyers has a negative impact on buyer's innovation because it determines an increase in negative spillovers and an increase in positive leakage at a decreasing rate. The strength of the focal buyer's direct tie with the supplier has a negative moderation effect on the relation between supplier's centrality and focal buyer innovation because when the indirect partner is a supplier, there is no need to prevent negative knowledge spillovers and a need to foster positive knowledge leakage. The relative strength of the direct tie between the buyer and the supplier versus the strength of the ties between this supplier and other buyers has a positive moderation effect on the relation between supplier's centrality in the network of buyers and focal buyer’s innovation output because when the indirect partner is a buyer (i.e., competitor), there is the need to prevent negative knowledge spillovers and the need to foster positive knowledge leakage. The latter case also shows that the combination of TCE and networks allows the consideration that transaction costs for a node are also a function of the attributes of the other transactions of its partners. The incentive a partner has to behave opportunistically is dependent on the opportunities or constraints it experiences in the transactions with its other partners. The likelihood of breaking a contract or violating common rules is a function of the benefits the actor can gain, not only in the specific relationship but in the set of relationships with all its partners. In this wider context, the TCE conclusion that the less the competition, the more likely is the exposure to a small amount of bargaining and opportunistic behavior is also useful.

Finally, with respect to innovation, the theoretical framework stresses that there is a trade-off between generation and appropriability of knowledge. While knowledge is inherently a public good, innovation output in the form of a patent is private. There is coexistence of competition for the appropriation of the innovation and collaboration because the partners contribute to the generation of novel ideas. It was interesting to relate these topics to the innovation function and particularly to the spillover and congestion effects (explained in Chapter 3).

As for this study's contribution to managerial practice, first of all, it is important to point out that the research problem addressed in the thesis is "grounded in reality"; this is a necessary prerequisite to be of interest for the managerial world. Many companies expand the scope of interaction with key suppliers beyond simple purchasing and transactions to joint research and development and sharing of strategic information. Moreover, I have explained how even in a traditional supply tie there can be different types of exchange such as product exchange, information exchange, and social exchange. The buyer, in order to get a competitive advantage, can exploit the contact points between its value chain and the supplier's value chain.

There is significant evidence that many companies view building partnerships in this critical vertical dimension of the value chain as crucial to their success. For instance, Gulati (2005), to explore the development of today's relationship-centred organizations, carried out a survey of Fortune 1000 companies across a range of industries, involving 122 CEOs and other senior executives from 1995 to 2002. They answered 115 questions on organizational challenges. The results show that 88 percent of survey respondents increased information-sharing with suppliers, 62 percent increased supplier participation in the development of products/services, 59 percent showed increased focus on promoting the longevity of supplier relationships, and 92 percent increased linkages to suppliers via computer networks.

"Deconstructed" firms are emerging in order to compete. Rebuilding value chains is becoming a fundamental strategic tool, and, accordingly, the focus on vertical relations characteristics is of greater significance. The thesis tries to identify some suppliers' characteristics that, in a network context like the one that firms are currently experiencing more and more, can be a driver for buyer's innovation. For practitioners, this thesis underlines the importance of scanning the external networks of their suppliers beyond their direct relationships with them. The supplier's selection should no longer be based only on firm-level characteristics (e.g., technical capabilities) or on dyadic supplier-buyer relationship characteristics but also on the suppliers' network of ties. The results of the empirical analysis can be perceived as advice on what type of nodes determine higher benefits if involved in a supply network and on what type of relations in a supply network firms should be developing. One of its strategic choices concerns the potential establishment of relationships with different levels of mutual involvement and collaboration. The literature has also acknowledged the existence of multiple types of ties simultaneously with the same supplier, but this topic has received little attention in previous studies.

There are several avenues along which the current work can be extended. First, the thesis can be the starting point for research focused on the multiplexity topic in supplier-buyer networks and for analyzing the interaction between different types of ties. Moreover, it can help explore how characteristics of one network of ties affect another network of ties. This would mean, for instance, isolating the impact of arm's length ties on alliances and vice versa or the impact of vertical ties (e.g., involving a buyer and a supplier) on horizontal ties (e.g., ties involving two suppliers or two buyers) and vice versa.

Second, here I focused on the supplier as a strategic broker between buyers. In the same manner, the buyer can be seen as a strategic broker between suppliers. The flow of information can also be from supplier to supplier, thus shaping competition in another way. I touched on this subject in Hypothesis Two; however, there is room to analyze the topic in depth. Also, the perspective of the supplier can be adopted while also considering a supplier's performance as a dependent variable.

Third, the availability of a multiplex network and, consequently, multiple types of ties allows a deeper analysis based on the influence of the single type of tie on the network dynamics that influence a buyer's innovation.

Furthermore, the level of competition among a buyer’s direct suppliers can play a role. If there is high competition, suppliers would be not willing to assume an opportunistic behaviour because of the threat of substitution. A high level of competition among suppliers raises the suppliers’ propensity to collaborate with the firm and, consequently, the firm’s innovation rate. This competition also has another meaning if mixed with cooperation in a competition strategy spurred by the buyer. A buyer’s strategy of competition among suppliers aims at keeping a constant and intense transfer of material and information among the actors, discouraging opportunistic behaviours (Dagnino, Padula, 2002). These aspects could be taken into account for future studies. Also, the work can be enriched by considering the decision of vertical integration (i.e., the “make” option) and not just the “buy” and “hybrid” options.

Finally, an inter-temporal approach can be adopted to assess the impact of ties in supplier-buyer networks on a buyer's innovation output. This means exploring past relations as determinants of relations in subsequent years and, consequently, element influencing a focal buyer's innovation. These and other perspectives could be analyzed in future research.

LIST OF TABLES AND FIGURES

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