EVOLUTIONARY DYNAMICS OF INTER-FIRM NETWORKS: A COMPLEX SYSTEMS PERSPECTIVE

Giovanni Battista Dagnino, Gabriella Levanti and Arabella Mocciaro Li Destri

ABSTRACT

This chapter aims to identify the main determinants that define the architectural properties of network emergence and significantly influence the dynamics underlying network evolution in time. The identification and analysis of these determinants, as well as the dynamic processes tied to them, allows to appreciate the competitive bases and consequences of network morphology. To this purpose, using a complex systems perspective as an integrative conceptual approach, we represent networks as complex dynamic systems of knowledge and capabilities. We perform a comparative in-depth analysis of the processes underlying the emergence and evolution of STMicroelectronic's global network and of Toyota's supplier network in the US so as to allow an elucidatory empirical assessment of the theoretical representation elaborated in the article.

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INTRODUCTION

During roughly the same time period (from the end of the 1980s to the beginning of the new millennium), Toyota Motor Company and STMicroelectronics were both engaged in setting up a complex network of inter-firm relationships. In both cases, the creation and evolution of the network was aimed to enable the focal firm to acquire and sustain a *dominant* competitive position in its industry. Though the industries in which these firms compete are different, they are similar in that strong capabilities in technology and operations are the fundamental aspects on which firm success rests. The scrutiny of the processes underlying the genesis and dynamics of these networks shows that in both cases there are three significant phases through which they emerge and evolve and, furthermore, that within each phase the contents of the evolutionary process are the same.

Despite the fact that the two cases mentioned above show numerous strategic similarities and an extremely similar process underlying their emergence and evolution, if we compare the resulting networks it becomes apparent that the differences in the structural outcome of the two endeavors is striking. In particular, Toyota Motor Company's network is characterized by strong relations between densely connected firms, a strong network identity and unity of vision. In this case, the evolutionary pathway of the network is largely defined by all the firms belonging to the network itself. STMicroelectronics's network, on the other hand, includes a wide variety of actors, most of whom maintain relationships with the focal firm but are scarcely connected to one another. This case shows the emergence of a loosely coupled network in which STMicroelectronics plays the principal role in determining the directions towards which the network will further develop.

The short example above draws attention to the following question: how come networks that have emerged and developed during the same time period, that are aimed towards the same objectives and whose evolutionary processes are composed of the same phases, have matured such stark opposite morphologies?

In order to be able to answer questions like the one above, the strategic management field needs to enhance its appreciation of the evolutionary dynamics of inter-firm networks. In fact, albeit the great advancements made in the last decade, existing research on networks appears mainly static (Ahuja, Soda, & Zaheer, 2007) as it looks at network *structure* more than at network *processes*. As a result, it has an incomplete comprehension regards how networks evolve over time and the fact that the way such evolution occurs can be the source of relevant advantages and distinctive competitive positions both for the single firms belonging to the network and for the inter-firm system per se.

This chapter aims to pinpoint the main determinants that define the architectural properties of network emergence and that significantly influence the idiosyncratic dynamics underlying network evolution in time. The identification and analysis of these determinants, as well as the dynamic processes tied to them, also allows to appreciate the competitive bases and consequences of network morphology.

To the extent that the processes underlying network emergence and evolution may be systematically influenced by the intentional actions taken by pivotal firms and, furthermore, considering the competitive consequences tied to different network morphologies, it becomes of interest for firm executives to identify a limited number of variables which may be leveraged and managed in order to direct the evolution of the network they participate in towards a specific strategic aim and coherently with the requirements of the competitive domain in which they compete.

In order to make such a contribution, we have structured the chapter in two main parts: the first is dedicated to the elaboration of a theoretical framework which consents to represent the main determinants and dynamic processes underlying inter-firm network evolution. The second part is aimed to confront the theoretical framework elaborated with the longitudinal qualitative analysis of two case studies in order to assess its capacity to deliver a satisfactory explanation of the emergence and evolution of inter-firm networks.

More in detail, in the first part of the chapter (i.e., the next two sections), we use the holistic and multilevel logic provided by the complex system perspective (Morin, 1977; Prigogine & Stengers, 1984; Anderson, 1999) to integrate and extend the hints of two relevant management approaches: the *knowledge-based theory of the firm*, which focuses on the individual firm and explains the growing importance of its internal idiosyncratic knowledge and capability base in the generation and renewal of the firm's competitive advantage (Nonaka, Toyama, & Nagata, 2000; Nonaka & Toyama, 2002); and the *strategic networks approach*, which underscores the necessity to extend the boundaries of strategic investigation from the single firm to the network of relationships in which firms are embedded, given that the value-generating capability increasingly rests at the network level rather than at the individual firm level.

The integration of the two conceptual approaches above brings us to sketch an interpretative analytical framework of inter-firm networks which

(a) considers the strategic network as a distinct conceptual macro-category that, by embracing and interconnecting a variety of idiosyncratic firms, originates a complex dynamic system of knowledge and capabilities;
(b) underscores that, within an inter-firm network, we can identify three relatively distinct but complementary and coexisting levels of analysis: (1) the *micro-systemic level*, related to the single firm in the network; (2) the *meso-systemic level*, related to the various groups of densely connected firms within the network. These firms maintain particularly intense – dyadic or multiple – relationships vis-à-vis those held with the other firms that belong to the network; (3) the *macro-systemic level*, which concerns the network system as a whole, and the relationships between the latter and the environment in which it operates. Each of the levels is in turn characterized by an idiosyncratic language, a specific pool of knowledge and capabilities and a semi-autonomous pace of evolution;
(c) emphasizes that the evolutionary pathway of the inter-firm network, taken equally as a whole and in its single parts, stem from the dynamic processes which occur at each one of these levels and in the interactions that inescapably arise (partly in an intentional fashion and partly spontaneously) among its three different levels. These complex dynamic interactions are able to generate a superadditive expansion of the (synchronic and diachronic) cognitive potential within the inter-firm network.

Once we have turned out the skeleton of our interpretive analytical framework, in the second part of the chapter (i.e., the few successive sections), we apply it to scrutinize the emergence and the evolutionary dynamics of the two business cases briefly mentioned above – i.e., Toyota Motor Company's endeavor to replicate its Japanese network of first and second tier suppliers in the USA and the emergence of STMicroelectronics's complex network spread worldwide. By adopting a multiple-case comparative approach, we use the framework elaborated in the first part as an operational template to determine how closely empirical observations concerning the two cases chosen match it. Finally, we apply replication logic to draw a few analytical generalizations from the particular set of empirical results obtained. The chapter ends with a section of final conclusions and the illustration of a number of interesting aspects and implications which emerge from this study and need further development.

REPRESENTING INTER-FIRM NETWORKS THROUGH THE INTEGRATION OF THE KNOWLEDGE-BASED THEORY OF THE FIRM AND THE STRATEGIC NETWORK PERSPECTIVE: TOWARDS A COMPLEX SYSTEMS VIEW

Shifting the Focus of Strategic Analysis from the Single Firm to the Network

The emergence of the resource-based view of the firm in strategy studies during the 1990s may be seen as the first systematic and comprehensive attempt to scrutinize the firm level sources of competitive advantage. As a by-product, analyses conducted in this vein also laid the groundwork for the elaboration of what may be considered a kind of 'theory of the firm' that is specific to the strategy field (Mocciaro Li Destri & Dagnino, 2005). Stemming from these studies, as of the mid-1990s, the strategy field saw the development of what is known as the knowledge-based theory of the firm (KBT). The latter approach is characterized by an emphasis on the role of knowledge as a determinant of firm competitive performance and the elaboration of more dynamic views of the firm. Independently from the elaboration of what may be considered a 'theory of the firm', at the end of the 1990s and through the dawn of the new millennium, a stream of research in strategy literature began to draw attention to the necessity to extend the boundaries of strategic investigation to the network of relationships in which firms are embedded. This stream is known as the strategic network perspective (SNP) and focuses attention towards the possibility for networks to provide participating firms with access to valuable resources, capabilities and knowledge.

In the attempt to elaborate an analytical framework able to represent and capture the main determinants and processes underlying network evolution and emergence, whilst embracing both firm- and network-based sources of competitive advantage, in the sections that follow these two approaches will be succinctly illustrated and the potential for their integration will be explored.

The Knowledge-Based Theory of the Firm

Focusing on the individual firm and its internal idiosyncratic knowledge and capability base, the KBT explains the burgeoning relevance of knowledge in the generation and renewal of the firm's competitive advantage. The initial formulation of the KBT adopted an essentially static perspective as it conceptualized the firm as an organization that develops superior capabilities to protect (Porter-Liebeskind, 1996), integrate and apply the knowledge residing within single individuals (Grant, 1996a). More recently, the KBT has evolved toward a dynamic perspective since it views the firm as an entity which *continuously* creates knowledge (Nonaka, 1994; Nonaka et al., 2000; Nonaka et al., 2002).

In this second KBT perspective, the knowledge which a firm possesses or controls and the capability to create and deploy such knowledge are the primary sources of a firm's sustainable competitive advantage. The second KBT perspective claims that knowledge is a dynamic and *relational* phenomenon generated by the activation of different levels of social interaction, involving the interplay between two epistemological dimensions of knowledge (tacit and explicit). Through the dynamic interactions among the individuals belonging to the firm (and between these individuals and the environment) that occur in various shared contexts[1] (Nonaka & Toyama, 2002), firms manage to mobilize and organizationally amplify the individual tacit knowledge bases and to crystallize such knowledge at higher ontological levels (such as the group level, the organizational level and the inter-organizational level).

In order to be able to shift the focus from the single firm to the inter-firm network, it is necessary to integrate this body of literature with studies regarding the external environment in which the firm operates and, in particular, with studies that consider the social and economic ties which reciprocally connect firms on a non-spot basis.

The Strategic Networks Perspective

Moving from the recognition that the value-generating capability increasingly rests at the network level rather than at the individual firm level, the SNP underscores the necessity to extend the boundaries of strategic investigation to the network of relationships in which firms are embedded (Gulati, 1999; McEvily & Zaheer, 1999, Gulati et al., 2000). Strategic networks are networks in which enduring inter-organizational ties are strategically important for the firms embedded in them. They potentially provide participating firms with access to valuable resources, capabilities and knowledge, that are not fully owned or controlled by their internal organizations (Lavie, 2006), and with advantages from learning, scale and scope economies. In order to consider the role of the *external* sources of competitive advantage, the SNP introduces the notion of *network resources* (Gulati, 1999). The latter are resources that emerge from the firms' participation to the network, as they are inherent to the network rather than to the single firm.

In addition, the SNP underscores that the ability of a single firm to benefit from network resources originates from the interaction of three components: its own endowment of unique resources, capabilities and knowledge; its network position; and the structure of the network itself (Gulati et al., 2000; Zaheer & Bell, 2005). In sum, studies in this vein contribute significantly to our understanding of the social structure in which firms become entrenched once they begin to participate to a network, whilst they do not unveil the elements and processes which characterize single firm existence and performance.

The Integration of the Knowledge-Based Theory of the Firm and the Strategic Network Perspective

Though succinct, the description of the two branches of research in strategy studies offered above is sufficient to outline their main traits and underscore that they are potentially *complementary* in the explanation of the essence and dynamics underlying inter-firm networks. The first stream of research allows a dynamic representation of the single firm and of the processes which drive its evolution, as well as an analysis of the sources of firm-based competitive advantages. The second body of studies focuses attention on the different ties firms may create in order to interact on a stable basis with other counterparts and on the economic and competitive advantages these ties may deliver. This perspective, therefore, allows to contextualize the firm within a web of social connections that form a structure through which information and knowledge flow. From a methodological vantage point, the possibility to integrate these two perspectives in order to gain a more complete view of inter-firm networks rests in the consideration that neither one of them is *deterministic*; i.e. outlines necessary and sufficient conditions for explaining inter-firm networks in all their relevant aspects (Baum & Dutton, 1998). This potential for integration is further sustained by the common emphasis accorded to socially embedded interaction between agents (see Table 1).

The integration of these two bodies of research, leads to the elaboration of a theoretical framework of inter-firm networks in which

(a) attention is focused towards the role of knowledge exploitation and exploration, as – coherently with the view underlying the KBT – these

Table 1. Knowledge-Based Theory of the Firm and Strategic Networks Perspective Compared.

	Knowledge-Based Theory of the Firm	Strategic Networks Perspective
Level of analysis	The individual firm	The firm in the network of relationships
Unit of analysis	Knowledge and capabilities	Inter-firm relationships Network resources
Focus	Sources of firm-based competitive advantages	Sources of network-based competitive advantages
Limitations	Does not consider the external sources of competitive advantages	Does not buttress a *real* shift from the single firm to the network level of analysis
Main contributions taken into account	Nonaka (1994); Nonaka et al.(2000) and Nonaka and Toyama (2002)	Gulati (1999); McEvily and Zaheer (1999) and Gulati, Nohria, and Zaheer (2000)
Commonalities	None of them is fully deterministic Common emphasis accorded to socially embedded interactions among agents	

processes are considered the primary forces underlying firm and inter-firm evolution, performance and survival;

(b) the attention paid to knowledge and its dynamics in the KBT also allows to underscore the *social* nature of knowledge transfer and creation, as well as the crucial role played by *shared contexts* of interaction to support knowledge-generating processes;

(c) the SNP provides the concepts relative to the social ties and contexts which span firm boundaries, allowing to represent the firm within a social structure of inter-firm relationships which support and facilitate the transfer of knowledge and information.

This view enables first to pinpoint the essential forces underlying the emergence of inter-firm networks. In particular, as the environment in which the firm operates becomes more turbulent, the driving forces triggering the firm's search for rents rest on a twofold strategy. On the one hand, the firm tries to appropriate as much value as possible from its existing set of knowledge and capabilities. On the other hand, it aims to create and renovate the sources of its competitive advantages by means of learning new ways of managing existing sets of knowledge and capabilities, developing new sets of knowledge and capabilities and matching changeable environmental conditions with valuable knowledge and capabilities. The unremitting tension to generate new knowledge and to amplify the value of the existing one forces the single firm to cooperate with other firms and, therefore, to join the network as the participation to an inter-firm network allows the firm to access superior economic and cognitive opportunities.

The framework obtained from the integration of the KBT and the SNP offers an interpretation of the dynamics underlying, and the strategic relevance of, the cognitive aspects related to inter-firm ties and shared contexts. Though this seems a significant advancement in the comprehension of inter-firm dynamics, it is necessary to underscore that the framework outlined up to now draws its view of networks directly from the SNP. We argue that the latter perspective presents limitations which hinder the full appreciation of the processes underling network dynamics and performance.

Limitations of the Strategic Networks Perspective

In order to clarify these limitations, it is necessary to render explicit the view of inter-firm networks which is entrenched in the SNP. In particular, though the SNP has significantly contributed to shift attention towards the empirical and theoretical relevance of firm networks within management studies, it may be argued that this research stream does not buttress a *real* shift from the single firm to the network level of analysis. In fact, studies conducted within the SNP focus attention on the firm and analyze how 'a firm's networks allow it to access key resources (knowledge and capabilities) from its environment' (Gulati et al., 2000, p. 207). By considering the firm and its social context, the SNP underscores that the social ties in which a firm is embedded, thanks to its participation to the network, allow it to access and leverage informational advantages. These advantages consent firms to expand the perception of opportunities and the access to complementary resources necessary to grasp such opportunities. This perspective, however, limits the analysis of networks to coupling a single firm to its external social factors, and therefore fails to capture the distinctive dynamic aspects which underlie the evolution of the network as *itself* a complex system of knowledge and capabilities. In this respect, the SNP actually *underestimates* the social advantage provided by the complex inter-firm endowment of knowledge and capabilities. The latter advantage may be appreciated only if networks are considered as entities which are fully accomplished wholes able to perform *autonomous* strategic choices. Since the network is seen as key to access external valuable resources, but not as an entire whole fully accomplished to perform strategic choices by itself, this means that the greater part of the network literature actually supports a firm's perspective more than a network perspective.

In order for the theoretical framework elaborated in this chapter to overcome the limitations tied to the firm centered perspective which permeates the SNP, we turn to the complex systems theory and use it as an interpretive lens. The complex system theory allows us to transcend the mere integration of the KBT and the SNP, and to *expand* these perspectives and concepts towards the analysis of both the network as a whole and of the different levels which define the fundamental structure of the network. We suggest that this further reinterpretation of the bodies of literature chosen as conceptual bases of the framework proposed shifts the focus from the single firm to the network and its multiple relevant levels of analysis. This step is indispensable in order to capture the various different cognitive processes and social structures which systematically influence network evolution and performance, extending the ability to embrace both the firm- and the network-based determinants of competitive advantages. Accordingly, in the following sections we proceed to describe the main traits of the complex system theory and to illustrate the representation of the inter-firm network resulting from the adoption of this theory as an interpretative lens through which to re-elaborate the KBT and the SNP.

THE COMPLEX SYSTEMS THEORY AS A HOLISTIC AND MULTILEVEL LOGIC TO SCRUTINIZING PHENOMENA

Building on the tenets of the general systems theory (von Bertalanffy, 1969), the complex systems theory (CST) focuses on the properties, the structures and the evolutionary patterns of complex systems that operate in dynamic and potentially discontinuous environments. Developed primarily in biology and physics (Prigogine & Stengers, 1984; Maturana & Varela, 1987; Waldrop, 1992; Kauffman, 1993), thanks to its pervasive and interdisciplinary framework, the CST is progressively gaining an intriguing role also in management and organization studies (McKelvey, 1997, 1999; Cohen, 1999; Anderson, 1999; Axelrod and Cohen, 2000).

The transfer of concepts stemming from the CST to strategic management requires attention in order to avoid uncritical applications and possibly misleading interpretations. Nonetheless, the application of the CST to strategic management has a significant potential in informing (and transforming) research in the field as it provides researchers with a valuable set of insights and tools that embody a distinctive point of view and suggest new kinds of questions.

In this chapter, we stress that the CST is able to increase our understanding of the evolutionary dynamics of inter-firm networks, or how inter-firm networks emerge and evolve over time. Conceiving the firm network as *a complex and dynamic system* made of a variety of firms that, interacting, give shape to the evolutionary pathway of the system as a whole, we consider the network as a distinct conceptual macro-category that extends the economic potential of the single firms of which it is composed (Dagnino, 1999, 2004). In addition, as the evolutionary pathway of the network is due to the dynamic interactions among the different firms which belong to it, we underscore that an in-depth comprehension of the process of network evolution relies on the simultaneous consideration of the different, but nonetheless coexisting and coevolving, levels of interaction that occur inside the network; i.e., the firm level, the inter-firm group level and the network level.

Distinctiveness of Complex Systems Theory as Relates to Inter-firm Networks

Conceptualizing and analyzing inter-firm networks in the light of the CST, we take advantage of the following properties of complex systems (see Table 2).

(a) *Emergence*. Some patterns and properties of the firm network result from the spontaneous interactions of the firms participating in it, rather than being influenced by intentional managerially coordinated or controlled behaviors.
(b) *Self organization*. The inter-firm network exhibits self-organizing behaviors accomplishing an endogenous dynamic process thanks to which it spontaneously becomes increasingly organized. Accordingly, the network continuously shapes and reshapes itself, modifies its boundaries, creates and recreates its set of knowledge and capabilities in connection with environmental dynamics.
(c) *Path dependence*. The way a network behaves depends on the interaction between the stimuli it receives and the structural elements that define its nature and state in a given moment in time and space. It is noteworthy that the structural state of the network is the product of the

Table 2. Distinctiveness of Complex Systems as Relates to Inter-Firm Networks.

Concept Drawn from Complex System Theory	Short Description
Emergent properties	Some patterns and properties of a complex systems result from the spontaneous interactions of their components
Self organization	Starting in a random state, complex systems usually evolve towards order instead of disorder
Path dependence	Historical- and path-dependent contingencies influence the state and the behaviors of complex systems
Organizational closure	The organization of the complex systems is unchanged and identifies the system per se
Thermodynamic openness	Complex systems import energy from the external environment
Complexity	Complex systems are made of different and intertwined complex subsystems at different interacting levels
Coevolution	The adaptation of complex systems emerge from the adaptive effort of their components attempting to improve their fitness functions

accumulation of knowledge and capabilities that has occurred in the past. Therefore, it synthesizes past behaviors of the network itself. This means that historical contingencies play a role in influencing the state and behaviors of the network.

(d) *Organizational closure and thermodynamic openness*. The firm network is at the same time organizationally closed and thermodynamically open; namely, it is an autonomous system. Closure refers to the order that defines the *organization* of the network (i.e. the set of relationships that connect the various components) and allows to identify the network per se, regardless of the network's specific *structure* in any given moment in time and space. Openness concerns the energy exchanges of the network with the external environment (in terms of resources, knowledge and capabilities). As a consequence, the stimuli stemming from environmental dynamics can selectively activate structural changes inside the network (i.e., its adaptation) in order to preserve its organizational closure and to secure its survival over time.[2]

(e) *Complexity*. The inter-firm network is a complex system made of a set of independent firms (which are complex subsystems per se) that are connected to one another by feedback loops in order to create an 'organized complex unity' (Morin, 1977, 2001), a sort of *unitas* *multiplex*. Complexity entails considering simultaneously two antagonistic but complementary notions: the multiplicity of the single firms in the network and the 'oneness' of the whole network accomplished through its organization. As a result, the network is simultaneously *something more and something less* than the sum of the participating firms. It is something more, because properties that otherwise would not exist emerge through the organization of the parts. It is something less, as the organization imposes conditions that partially inhibit the potentialities of the parts.

(f) *Coevolution*. By striving to improve a fitness function over time, each firm in the network continuously adapts to the other participating firms in the network and to the external environment (Anderson, 1999; Lewin & Volberda, 1999; Volberda & Lewin, 2003).

Summing up, we maintain that the continuous interactions taking place within the inter-firm network rest on both internal and external stimuli. The internal stimuli derive from the coevolutionary processes activated by the intertwined and coadapting firms of the network. The external stimuli originate from the coevolution between the network as a whole and the external environment. Thanks to the self-organizing capabilities and emergent properties that the network possesses, these continuous interactions generate the evolutionary dynamics of both the network as a whole and the single firms embedded in it.

Whole-Parts Interaction

The analysis of the inter-firm network regarded as a complex and dynamic system is grounded in the coexistence and the dynamic interactions between the whole and the parts (Baum, 1999; McKelvey, 1999). As a consequence, the adoption of the CST to conceptualize and scrutinize inter-firm networks allows us not only to curtail the relevant antagonism between holism[3] and reductionism,[4] but also to assign a role to both the single parts and the whole in the emergence and evolution of the inter-firm network (Fontana & Ballati, 1999). Thus, it becomes possible to appreciate the new and different properties which emerge from the interactions of autonomous firms and crystallize at different levels within the network. At the same time, the variety and the autonomy of the firms participating in the network that cannot be inferred from the analysis of the network as a whole are not lost; on the contrary, they are underscored.

Holistic Logic

More in detail, the holistic logic that the CST provides us with makes it possible to unveil the synergies that a set of different and interrelated firms that cooperate together can achieve. Taking advantage of its holistic logic, the CST framework is able to shed light on the relevance of the interactions occurring among the firms belonging to the network. These interactions are of crucial importance since it is through them that the evolutionary pathway of the network emerges. Additionally, the interactions among the firms take place at multiple levels within the network. At all levels the evolutionary dynamics are significantly influenced by the interactions which come about at the lower and the higher levels of the firm collections within the same network (McKelvey, 1997). This multilevel logic is capable of scrutinizing complex organizations and paves the way to examine simultaneously the coexisting and coevolving levels of interaction which happen inside the network and the consequent cross-level effects.

The integration and extension of the KBT and the SNP through the lens of the CST allows us to sketch and advance an interpretative analytical framework of the inter-firm network that looks at it as a complex dynamic system of knowledge and capabilities. In order to explain the evolutionary dynamics of the network over time, the framework calls attention to the *cross-level effects* between the different network levels and emphasizes the unique and relatively autonomous nature of the firm network. Accordingly, we maintain that it is possible to identify the network by means of its idiosyncratic complex bundle of knowledge and capabilities and its functional specialization vis-à-vis the external environment.

THE INTER-FIRM NETWORK AS A COMPLEX DYNAMIC SYSTEM OF KNOWLEDGE AND CAPABILITIES

Integrating concepts drawn from the KBT and the SNP by means of the adoption of the CST, we sketch an interpretative analytical framework that considers the inter-firm network a distinct conceptual macro-category. Embracing and interconnecting a variety of idiosyncratic firms, this macro-category originates a complex and dynamic system of knowledge and capabilities which is able to stretch the cognitive scope both of the network as a whole and of the participating firms (Dagnino, 1999, 2004).

More in detail, within the network a set of specialized firms cooperate in order to jointly achieve more efficient, effective and timely processes of knowledge exploitation and exploration. Cooperative activities occur in various contexts of interaction scattered within the network. These contexts of interaction are a reinterpretation in cognitive terms of the nested bundle of inter-firm relationships. They identify *shared contexts* that possess specific time and space properties. Within these shared contexts, groups of firms exchange valuable existing knowledge and capabilities and/or co-produce new knowledge and capabilities.[5] These different contexts of interaction intermingle dynamically and are reciprocally interconnected so as to form a single overarching *shared space* that embraces all the shared contexts and therefore the network as a whole.

Within these specific contexts of interaction, the various participating firms are able to develop a set of capabilities. More in detail, they share information, knowledge and capabilities, interpret information and transform it into knowledge and produce new knowledge through the creation of new meanings and new contexts. The latter activity paves the way to the emergence of a common language that is integrated and shared among all the interacting firms.

Multiple Analytical Levels of the Inter-Firm Network

In order to pinpoint the different levels of analysis that are crucial to achieve an adequate representation and interpretation of network dynamics, we look at the *connective* structure of the inter-firm network. This structure is made of a nested bundle of inter-firm relationships. Such relationships may be dyadic or may extend beyond multiple units so as to encompass all the firms belonging to the network. Their intensity depends on the goals they pursue and the coordination mechanisms on which they rest. From a knowledge-based perspective, inter-firm relationships are relevant to the extent that they contribute to the cognitive processes which occur in the network. We are therefore looking for the different shared context of interaction and their distinctive characteristics relative to the way knowledge is transferred and created. Given this criterion, in the complex and dynamic system of knowledge and capabilities which constitute inter-firm networks it is possible to single out three levels of analysis (epitomized in Fig. 1).

(a) The micro-systemic level, which identifies the knowledge and capabilities related to the single firm belonging to the network.

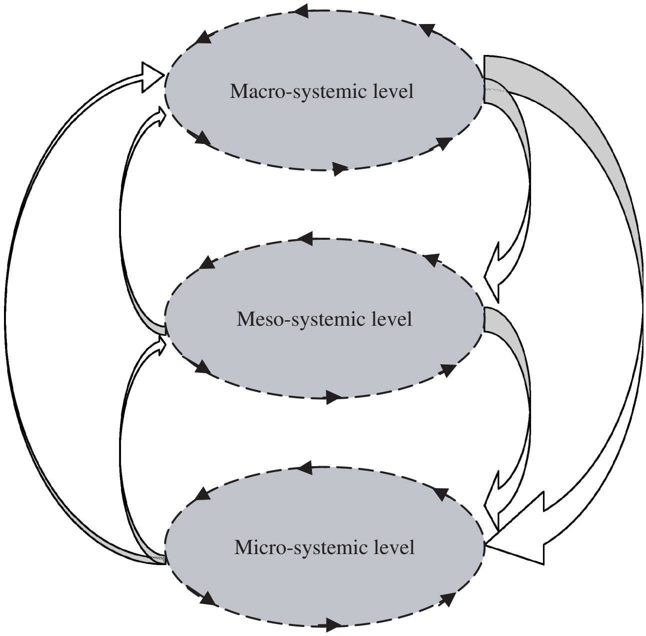

Fig. 1. The Three Analytical Levels of the Inter-Firm Network and Their Mutual Interactions.

(b) The meso-systemic level, which includes the knowledge and capabilities associated with dense inter-firm groups within the network.
(c) The macro-systemic level, which embraces the knowledge and capabilities available to all the firms participating in the network.

The adoption of the holistic and multilevel logic that the CST provides us with consents to shed light on the dynamics underlying the networks' evolution. In particular, it is able to grasp, on the one hand, the specific role of each of the three analytical levels identified above and, on the other, the effect of the interaction among these three levels on the evolutionary pathways undertaken by the network.

More in detail, at the *micro-systemic* level, each firm autonomously tries to extract rents from both amplifying the value of the existing set of knowledge and capabilities that it possesses or controls and generating new valuable knowledge and capabilities. In order to achieve this goal, the firm carries out idiosyncratic and specific processes of knowledge exploitation and exploration. These processes are driven by its own set of specialized cognitive assets but also leverage the potential of the set of knowledge and capabilities available at the meso-systemic and the macro-systemic levels. The capability of the firm to take advantage of the cognitive assets shared at higher analytical levels is deeply associated with the capabilities to pick up, absorb and integrate these assets with the internal ones (Cohen & Levinthal, 1990; Grant, 1996b).

At the *meso-systemic* level, idiosyncratic firms confront and interact with each other in shared contexts that are characterized by specific and definite cognitive goals. By means of mutual confrontation and interaction, the firms connected by strong ties in dense groups jointly achieve processes of learning and co-generation of knowledge, that lead to the emergence of a shared and integrated knowledge base and a common language. Moreover, as the firms work together and reciprocally adapt over time, they turn out to be more mutually coherent and isomorphic. As a result, they tend to reach marked heuristic homogeneity and a harmonious specificity that allow to carry out smoother and quicker sharing and transfer of both tacit and explicit knowledge (Dagnino, 1999). Additionally, repeated interactions between these firms are able to develop mutual commitment and an atmosphere of trust that foster open-ended cooperation, sharing of valuable (tacit and explicit) knowledge and curb the risk of opportunistic behaviors (Coleman, 1988; Uzzi, 1997; Kale, Singh, & Perlmutter, 2000; Dyer & Hatch, 2006). Accordingly, the meso-level contexts display more rapid and direct confrontation and comprehension among participating firms, availability to openly share valuable knowledge as well as higher commitment and motivation to cooperate, in order to jointly carry out processes of learning and co-generation of knowledge. Over time, these conditions reinforce each other in a *virtuous circle* that overcomes the barriers to tacit and idiosyncratic knowledge transfer and, more in general, increases the efficiency, the efficacy and the speed of knowledge transfer, sharing and co-production within the meso contexts of interaction (Capaldo, 2007).

At the *macro-systemic* level, heterogeneous and specialized firms and dense groups of firms that jointly form the network are intertwined and interact dynamically so as to yield a single shared space (in this vein Dorejan, 2008, conveys ‘the global network view’). Within this shared space, the connections among the participating organizations are weaker vis-à-vis those that take shape at the meso-systemic level (Burt, 1992; McEvily & Zaheer, 1999; Baum, Calabrese, & Silverman, 2000; Zaheer & Bell, 2005). Accordingly, over time the interactions occurring within the shared space drive to the emergence of a common knowledge base and a shared language that are more general in relation to the ones developed within the firm groups at the meso-systemic level. By means of the peculiarities that the shared space exhibits (i.e., nested web of weak ties between idiosyncratic organizations and general joint knowledge bases and languages), within this space it is possible to achieve processes of transfer and sharing of information and of explicit and general knowledge that entail lower costs and higher speed.

Additionally, thanks to the weak connections and the confrontation of a plurality of heterogeneous and specialized firms and inter-firm groups, the macro shared space displays significant levels of variety and variability of the knowledge and the capabilities that reside within it. Thanks to the conditions above, the sets of knowledge and capabilities within the network tend to match (diachronically and synchronically) with the changeable environmental conditions and, therefore, to preserve and increase over time the value of the complex system of cognitive assets in relation to the environmental dynamics.

Network Multilevel Architecture

The interpretative analytical framework sketched above allows us to underscore that the inter-firm network has an indubitable *multilevel* structure. This structure takes shape vis-à-vis the specific cognitive necessities and the characteristics of the competitive and socio-institutional domain in which the firm operates. By underscoring this multilevel architecture, it is possible to show how inter-firm networks are able to create a very efficient, effective and flexible structure supporting cognitive processes of both knowledge deployment and creation. In particular, it is able to leverage the benefits of the strong connections associated with the creation of specific shared contexts at the meso-systemic level. Within these contexts, the availability to openly share valuable knowledge, the mutual commitment and the motivation to cooperate promote a virtuous cycle that results in superior processes of tacit and explicit knowledge transfer as well as the co-production of new knowledge and capabilities.

Strong Ties and the Risk Inward Looking Myopia

Whilst the meso-level of dense interactions supports the co-generation of complex knowledge between firms, the macro-level of weak interactions overcomes the limitations and risks related to using only strong ties within inter-firm networks (Uzzi, 1997; Capaldo, 2007). More in detail, a number of authors in the network literature (Burt, 1992, 1994; Uzzi, 1996, 1997; Rowley, Behrens, & Krackhardt, 2000; Hagedoorn & Duysters, 2002; Nooteboom, 2004) have shed light on the tendency for strong ties to give way to processes of homophily, whereby firms who interact intensely tend to become reciprocally isomorphic, leading to a decrease in the variety of their knowledge endowments. This circumstance emphasizes the risk[6] that firms belonging to the same dense group may mature an inward looking myopia which limits the firms' ability to sense the emergence of opportunities or threats connected to changes in the external environment as well as its capacity to adapt to the changes perceived.

Inter-firm networks curb the aforementioned weaknesses associated to the strong ties of the meso-systemic level, by balancing them with an intertwined web of weak connections among a variety of heterogeneous and specialized firms and groups of firms at the macro-systemic level. The contribution weak ties make to the knowledge generation process within firm networks rests both in their capacity to maintain and nurture firm heterogeneity and the differentiation of knowledge and competences within the network, as well as being a valid support for highly efficient, effective and rapid processes of information sharing and brokerage and for the transfer of explicit and general knowledge between member firms.

We argue that the adoption of the CST as an epistemological base to reinterpret and integrate the KBT and the SNP consents, not only to reveal the layered and changeable structure of inter-firm networks, but also to find the rationale underlying the emergence and evolution of this structure and of the network itself. In particular, the network's initial structure emerges from the sets of knowledge and capabilities that reside within it and from the cognitive goals which are fixed at the outset. At each level, a semi-independent process of knowledge evolution occurs; the knowledge and capabilities created at each level are rendered available also to the other levels, sparking off further developments and contributing to their evolutionary process. These processes shape and endogenously stimulate further evolutions of the system and contribute to determine the effects of exogenous stimuli on the system too.

Firm- and network-based determinants of competitive advantage coexist and interact within the different and interconnected analytical levels of the network. By means of the self-organizing capabilities and emergent properties that the network possesses, this interaction engenders the economic and cognitive performance of the network as a whole and of its parts, as well as the network potential to develop and evolve over time.

Network Morphology and Multilevel Evolutionary Interactions

The morphology of a network in any given moment time and point in space may be intended as the reflection of the cognitive characteristics of the domain in which the network operates. In particular, according to the cognitive characteristics of the domain in which the network is operating, we would suppose to find that the role of the different levels changes in order to better fit and support the specific necessities tied to the transfer of information and knowledge, the signaling of different knowledge bases and the knowledge creation processes which are crucial in that domain.

Accordingly, it is worthwhile taking into account that the strategic interactions among the three analytical levels aim to implement top-down and bottom-up flows of information and knowledge (see Fig. 2). The two kinds of flows and interactions are characterized by different evolutionary intensity and frequency. The top-down flows refer to the knowledge and information that are available to all the firms participating in the network (at the macro-systemic level) and to the firms establishing inter-firm groups (at the meso-systemic level). Their activation depends on the firm and group capabilities to absorb these pieces of knowledge and information and integrate them with the internal ones and on their motivations to engage in behaviors that are efficient at the micro- and meso-systemic levels. These types of behaviors also spark mutual fertilizations and reciprocal stimuli that consent to increase the efficiency, the efficacy and the rapidity of

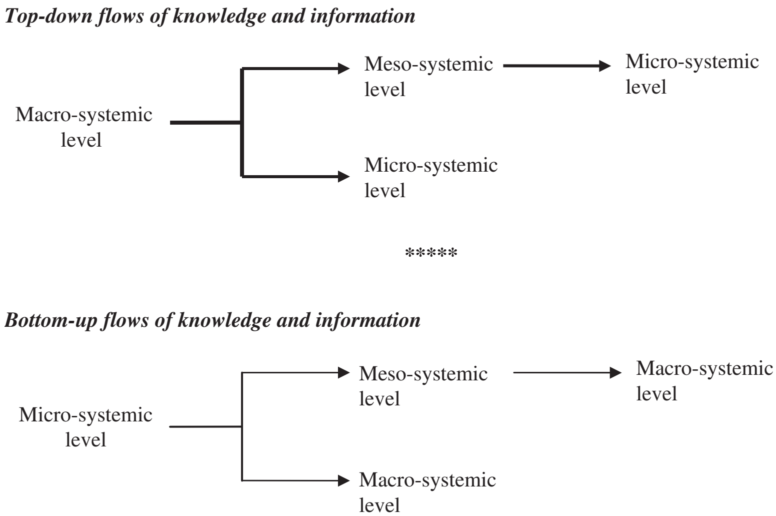

Fig. 2. The Flows of Knowledge and Information among the Three Analytical Network Levels.

cognitive processes that are accomplished at higher levels of the inter-firm network.

The establishment of bottom-up inter-level flows of knowledge and information entails two inescapable crucial problems: (a) the availability of the single firms and groups to openly share their valuable knowledge with other units and groups; (b) the nature of the transfer process, that especially with reference to tacit knowledge requires the creation of specifically geared shared contexts (that are designed to be functional to predefined learning purposes). As a result, the activation of these flows is strongly connected to: (i) the accomplishment of regular knowledge-sharing activities; (ii) the capabilities of the single firms and groups to sense the opportunities associated with intra-network interactions; iii) their motivation to activate the potential intra-network connections. Accordingly, it is worth mentioning that the firms embedded in the network play a critical role when they act as strategic brokers that are actually able to sew together the different information, knowledge and capabilities that reside within the three network levels.

RESEARCH METHODS AND DATA

In this chapter our aim is to increase the understanding of the main determinants that define the architectural properties of network emergence and significantly influence the dynamics underlying network evolution in time. In order to achieve this goal, we have sketched an interpretative analytical framework of the inter-firm network as a complex dynamic system of knowledge and capabilities. We now apply this framework to scrutinize the emergence and evolutionary dynamics of two business cases: Toyota Motor Company and STMicroelectronics.

Theoretical Sampling

The selection of the two cases under inspection relies on the basic principles of theoretical sampling (Pettigrew, 1990). Theoretical sampling suggests that the relevant cases are selected more than for statistical reasons on the basis of their relevance to our research questions and of their ability to replicate the analytical framework that has been developed (Glaser & Strauss, 1967, Mason, 1996).[7] We maintain that the study of cases is an appropriate research strategy to help us understand the phenomenon under investigation for three main reasons. First, the nature of our research question requires a process theory explanation of the temporal order and sequences in which a discrete set of events leads to an observable outcome. Understanding how networks evolve over time and why they evolve in a given way entails the scrutiny of the temporal ordering and the patterns of interaction among the participating firms. Second, using a qualitative process approach we take into account the context where the phenomenon unfolds. This leads to the consideration of multiple levels of analysis that, at first sight, are somewhat difficult to separate from one another. Third, collecting process data from several sources of empirical evidence, we attempt to document as thoroughly as possible the sequence of events pertinent to the evolutionary dynamics of the networks analyzed (Yin, 1994; Langley, 1999). Summing up, the study of cases allow us to transcend the surface description of the network phenomenon so as to penetrate the inner logic behind its observed temporal unfolding and, therefore, to recognize the underlying *generative mechanisms* that drive the emergence and evolution of networks.

In the first part of this chapter, taking a deductive approach, we have adopted the CST in order to sketch an interpretative analytical framework of the inter-firm network in which it is possible to integrate and expand the theoretical contributions of the KBT and the SNP. We use this framework as an operational template to determine how closely empirical observations concerning the two selected cases match it, or to assess the extent to which the framework developed contributes to a satisfactory explanation of the emergence and the evolution of the firm networks studied. Thanks to the multiple-case comparative approach, we apply replication logic to draw a few analytical generalizations from the particular set of empirical results obtained from the study of the two selected cases.

Multiple Cases with and Embedded Design

More in detail, we select sample cases from two different industry settings (i.e., the automotive industry and the semiconductor industry). This research strategy provides a better opportunity to detect possible differences and commonalities pertinent to the mechanisms underlying the emergence and the evolutionary dynamics of networks that operate in environments characterized by different innovation paces. Accordingly, if the findings of both cases match with the theoretical template, by using replication logic we will achieve a more general domain within which our results can be generalized and, in turn, strengthen the external validity of the developed analytical framework (Yin, 1994; Van de Ven & Poole, 2002).

In addition, rather than on the whole global Toyota's network of suppliers, our research strategy led us to focus attention on the network that connects Toyota to its first-tier suppliers as specifically concerns the Georgetown plant, Kentucky (USA). Incidentally, in this respect the study of Toyota case differs from the ST case that entails the analysis of its entire global network. This option rest on the consideration that, as it reproduces the same functions, structures, mechanisms and goals, the US-based Toyota's network is nothing else that a miniature model of the whole global Toyota's network of suppliers. Thanks to this option we are able, on the one hand, to surmount the empirical difficulties related to: (a) the extensive lifetime of the overall Toyota's network, which spans from 1937 to 2007, vis-à-vis the ST one, which has originated in 1987; (b) the massive volume of data that a comprehensive scrutiny of the Toyota's overall network would require in relation to its intricate configuration architecture. The intricacies above could jeopardize the internal validity of this study. On the other hand, since the two networks at hand are typified by similar overall time span, the research choice we have taken secures the full comparability of the miniature model of Toyota's network with ST's network.

Due to the stratified nature of inter-firm network architectures, we use multiple-case analysis with an embedded design. Each case study involves a multilevel structure that produces a scrutiny ranging over and across the three previously identified levels of analysis (i.e., the micro-systemic level, the meso-systemic level and the macro-systemic level). Coherently, we investigate the cross-level effects that occur within the network.

Temporal Bracketing

In addition, we use a temporal bracketing strategy by decomposing in each case the time scale into successive periods. This type of temporal decomposition offers captivating opportunities for structuring process analysis. Specifically, it consents to carry out both within-case comparisons across subsequent periods and cross-case comparisons that sustain the internal and the external validity of the study (Eisenhardt, 1989; Langley, 1999).

Sources of Data

In the scrutiny of the two chosen cases, we employ multiple data collection methods in order to combine them via triangulation of evidence. This strategy enhances the construct validity of our applied field research investigation. The development of converging lines of inquiry starting from a variety of sources of information allows more convincing and accurate findings (Eisenhardt, 1989; Yin, 1994). The collection of data includes: (a) documentary information, gathered from previous studies, research reports, books, scientific journals, business press articles, the Internet and others; (b) archival records, collected from the archives of the firms participating in the networks under investigation and (c) personal interviews, consisting in telephone and face-to-face interviews with key informers and executives. The information we have gathered refers to all the three levels of analysis of the inter-firm network.

It is noteworthy that, in order to reduce the problems associated with managing a wide and unstructured data bulk, we have codified all the collected data and developed both an electronic and a paper database, allowing us to insure the reliability of our study.

THE STMICROELECTRONICS CASE

STMicroelectronics N.V. (from now on ST) was created in 1987 from the merger of two European State-owned firms: the Italian 'SGS Microelettronica' and the French 'Thomson Semiconducteurs'.[8] Since its formation, ST pursued an aggressive growth strategy, investing heavily in R&D, establishing strategic alliances and industry partnerships, building up an integrated presence in the world's major economic regions, and honing one of the world's most efficient manufacturing operations. This strategy has allowed ST to rapidly become a global leader in developing and delivering semiconductor solutions across the wide spectrum of microelectronics applications.

Interestingly enough, crucial to the success of ST is the knowledge network that the firm has developed worldwide over time. This knowledge network consists of a web of strategic alliances and partnerships with key customers (that are generally world leaders in markets driven by the power of semiconductors), major suppliers and other semiconductor industry manufacturers, as well as joint R&D programs with leading universities and research centers throughout the world. ST's network is aimed at creating a complex system of knowledge and capabilities that enables ST to offer cutting-edge solutions to customers in all segments of the electronics industry.

In order to exemplify the emergence and the evolutionary dynamics of ST's network and the rationale underlying its materialization and evolution over time, the temporal bracketing strategy we have chosen to pursue has driven us to split the investigation period into three temporal phases (i.e., 1987–1991; 1992–1999 and 2000–2006). Equally for motives of investigational parsimony and information enhancement, the strategy of decomposing the time scale into successive periods appears to be a particularly fertile one in this applied field research investigation.

Phase I: 1987–1991

Starting its business in 1987, ST had to tackle two focal problems. First, the new management found economic and financial difficulties that were inherited from previous managerial logics. Second, they found themselves located in the 'wrong place'. Since they were headquartered in Italy and France, they felt geographically detached from the places in which key technologies and knowledge in the semiconductor industry were being developed, as well as from where the main firms using microelectronics applications were situated. The lack of technological and market knowledge in their home countries forced ST to become a global player. More in detail, they adopted a twofold strategy looking for the potential of knowledge trapped in pockets of local expertise scattered worldwide, and searching for customers in distant locations and in very different semiconductor applications. Additionally, as ST searched throughout the world for new clients, they dealt with the limitations associated with the use of standard semiconductors in satisfying a wide range of idiosyncratic customer needs. Accordingly, they developed awareness of the opportunity of neighboring the production of standard semiconductors with the creation of integrated and dedicated chips which could perform sets of functions needed for specific applications (the so-called System-on-Chip or SoC).[9]

In order to produce integrated system chips, ST needed to combine their technological and manufacturing knowledge and capabilities related to silicon with the knowledge and capabilities of the specific systems embedded within their customers. The need to integrate cognitive assets stemming from different sources, conducted ST to build strategic alliances with key customers in several industries. ST's customer firms were generally global leaders in key industries or of particular applications, such as: Seagate (United States) and Western Digital (United States) for disk drivers; Nortel (Canada) for telecommunications; Bosch (Germany) for automotive electronics; Thomson Multimedia (France) for video applications and Pioneer (Japan) for consumer electronics.

Aimed at co-developing application-specific products, these alliances provided ST with unique access to: (a) technological knowledge that was tacit and dependent on the specific context of the application it had to serve; and (b) market knowledge associated with the main microelectronics products. Later on, the knowledge and capabilities developed jointly with (or by means of) key customers located in different countries and specialized in a variety of applications were used to produce system chips for other customers with slightly different applications worldwide, to manufacture standard products and to develop next generation application-specific products. Additionally, these sources of knowledge were complemented by cooperating with leading universities (located in both the US and EU) and other major research institutions (such as CEA, IMEC and France Telecom R&D), as well as participating in European research programs (JESSY, 1989–1996).

Summing up, in the course of Phase I (1987–1991), ST started to develop a set of emergent, *quasi-spontaneous* connections that were generally in isolation or unrelated to each other. These connections laid the foundation for the emergence of a virtuous circle between the creation of new knowledge and capabilities and the exploitation of existing knowledge and capabilities (Doz, Santos, & Williamson, 2001).

Phase II: 1992–1999

Leveraging the base of relational capabilities (Powell, Koput, & Smith-Doerr, 1996; Lorenzoni & Lipparini, 1999; Kale et al., 2000) they had developed during the first phase, ST was able to reinforce the existing strategic alliances with key customers and lengthen the set of learning collaborations with other leader firms (such as Alcatel, Gemplus, IBM, HP, ATI Technologies, Ford, and others). More in detail, each ST alliance was characterized by specific and clear cognitive goals and a precise schedule. In order to manage each connection, ST created a dedicated unit that was designed to be functional for predefined specific learning purposes. Also, the firms cooperating with ST decided to shape a joint team that gathered at fixed dates (generally every 6–9 weeks). During these regular meetings, the members of the joint team became accustomed to juxtapose and combine the results stemming from the work carried out by each firm and to assess in progress the achievement of the predetermined cognitive goals.

Additionally, ST started establishing joint research and technological co-development projects with other manufacturers of the semiconductor industry; such as Philips NV (of the Netherlands) and Siemens (of Germany). The main driver of cooperation among competitors was the perception of a common challenge; i.e., the difficulty of the so-called '*game against nature*' associated with the miniaturization of the chips and the integration on a single die of entire systems with much functionality. This challenge exceeded individual capabilities and required competing firms to collaborate. By means of collaboration, these firms were able to reduce the costs and share the risks associated with huge R&D investments, as well as to gain access to new technological and manufacturing knowledge and capabilities.

During the second phase, ST continued and extended joint R&D programs with a variety of funding sources: (a) European research programs, such as JESSY (1989–1996), that later lead to MEDEA (1997–2001); (b) European technology platforms, such as ENIAC and ARTEMIS; (c) collaboration with leading universities (located in the US, Europe and Asia) and other major research institutions (such as CEA, IMEC and France Telecom R&D).

Additionally, ST took part in international consortia and associations (such as the International 330 mm Initiative, International SEMATECH, International Technology Roadmaps for Semiconductors) aimed at collectively building technology frameworks capable of supporting the firms' efforts to proceed along their technological trajectory.

ST also formed joint development programs with key suppliers (such as Applied Materials, ASM Lithography, Canon, Hitachi and others) and leading Electronic Design Automation (EDA) tool producers (such as Cadence, CoWare and Synopsys) in order to jointly define the technical standards of the facilities and equipments that ST needed to manufacture their products. Finally, in 1998, ST signed a joint venture agreement with Shenzhen High Tech Industrial Company Ltd (SHIC) to build a back-end assembly and test plant in Shenzhen, China.

Summing up, in the course of Phase II, a portfolio of strategic alliances and collaborations was built allowing ST and its partners to mutually achieve more efficient, effective and timely processes of knowledge exploitation and exploration. Notwithstanding that, it is noteworthy that ST's alliance portfolio was made of firms that usually did not interact with each other as the connections that were established among ST and their partners were not driven by a general coordination purpose of knowledge sharing. Consequently, at that time, ST's embryonic network was not yet a complex system of knowledge and capabilities.

Phase III: 2000–2006

In the course of the third phase (2000–2006), the analysis of the ST portfolio of strategic alliances underscores the creation of an intertwined web of firms mutually interacting by means of a first-class blend of both weak and strong ties. The interactions among ST and the firms participating in the ST's network led to the emergence and clear definition of a complex system of knowledge and capabilities and to its evolution over time.

More in detail, during Phase III ST persevered in their strategy of strengthening and widening the portfolio of strategic alliances and learning collaborations. These alliances mainly consisted of

(a) projects of product co-development with key customers (Table 3);
(b) programs of R&D with other semiconductor industry manufacturers and also main customers (Table 4);
(c) projects of co-development of equipments and EDA tools with major suppliers[10];
(d) European research programs,[11] European technology platforms[12] and international consortia (Table 4) and
(e) research programs with leading universities[13] and research centers.[14]

Comparing Tables 3 and 4, which draw the evolutionary pathways of the different alliances throughout the phase under investigation, it is possible to detect that each alliance over time tends to be revised and extended in its learning scope in order to respond to the new challenges in the semiconductor industry. Additionally, over time ST and its partners established new learning collaborations that included firms participating in different pre-existing alliances.

While ST and allied firms were working together in the context of the relationships they had established (i.e., at what we have called the 'meso-systemic level'), they were developing a set of common knowledge and capabilities, reciprocal commitment and an atmosphere of mutual trust, as well as a web of weak connections at the macro-systemic level. This situation, on the one hand, allowed for the emergence of superior capabilities of (tacit and explicit) knowledge transfer and the co-generation

Table 3. Main Clients of ST.

Markets	Clients		Focus Applications
Communications	Agilent	Nokia	Wireless
	Alcatel – Lucent	Nortel Networks	• Connectivity
	Ericsson	Philips	• Mobile phone
	Humax	Safran	• Portable multimedia
	Kyocera	Siemens	• Imaging
	Motorola	Thomson	Networking
Computer peripherals	Acer	IBM	Data storage
	Agilent Technologies	Lexmark	Printers
	Creative Technology	Samsung	
	Delta	Seagate Maxtor	
	HP/Compaq	Western Digital	
Automotive	Bosh	Hella	Powertrain
	Conti	Marelli	Safety
	Daimler Chrysler	Pioneer	Car body
	Delphi	Sirius	Car multimedia
	Denso	Valeo	
	Harman	Visteon	
Digital consumer	Agilet Technologies	Olympus	Set-top boxes
	Bose Corporation	Philips	High definition DVD
	Echostar	Pioneer	Digital and HD TV
	LG Electronics	Samsung	Audio
	Grundig	Scientific Atlanta	
	Hugues	Sony	
	Kenwood	Thomson	
	Matsushita	Vestel	
Industrial and multisegment	American Power	Magnetek	Power supply
	Conversion	Nagra	Motor control
	Astec	Oberthur	Lighting
	Autostrade	Philips	Metering
	Delta	Schlumberger	Smartcards
	Gemplus	Siemens	
	IBM	Toppan	
	Liton		

Source: ST documents.

Table 4. Alliances, R&D Programs and Consortia Initiated in the Course of ST's Phase III.

Years	Names	Members	Objectives
2000	Crolles 2	ST, Philips	Jointly building an advanced 12-inch (300 mm) wafer pilot fab
2000		ST, Ovonyx	Licensing and joint development program (Flash memory, MOS logic and other applications)
2001	Environmental 4	ST, Philips, Infineon Technologies	Development standard for lead-free products
2001	Joint venture SuperH	ST, Hitachi	Joint venture to develop RISC microprocessors
2002	Crolles 2	ST, Philips, TSMC[a]	Cooperate on process alignment for 90 nm CMOS generation and beyond
2002	Crolles2 Alliances	ST, Philips, Motorola (Freescale[b]), TSMC	Development CMOS technologies from 90 to 32 nm chip on 300 mm wafers
2002	OMAPI standard	ST, Texas Instruments	Establishment of an open standard for wireless applications
2003	MIPI	ST, Texas Instruments, ARM, Nokia (founding members[c])	Definition of open standard for hardware and software interfaces in mobile terminals
2004	NANOCMOS project	ST, Philips, Infineon Technologies, CEA Leti,[d] IMEC[e]	Project to propel Europe to limit of CMOS technology
2004	MINATEC IDEAs laboratory	ST, France Telecom, CEA Leti	Creation of a joint multidisciplinary laboratory
2004	Crolles2 Alliances/CEA	ST, Philips, Freescale, CEA	Research contract for development of 45 and 32 nm CMOS technologies
2004	Environmental 4	ST, Philips, Infineon Technologies, Freescale	Development standard for lead-free electronics packaging and promote a greener industry
2004	SMIA	ST, Nokia	Specification of Standard Mobile Imaging Architecture
2004		ST, HDIC[f]	Joint venture for digital TV software (Shanghai, China)
2004		ST, Hynix	Joint venture to build a front-end memory manufacturing facility in Wuxi City (China)

2005	Crolles2 Alliances	ST, Philips, Freescale	Extending the scope of their joint semiconductor R&D activities to include R&D related to wafer testing and packaging
2005	Crolles2 Alliances	ST, Philips, Freescale	Enhancing collaboration across libraries and SoC (LIPP)
2005	SOCOT	ST, KLA – TENCOR, IMEC, QWED	Consortium to determine a complete solution for overlay measurements for 45 nm generation USLI devices and below
2005		ST, Intel	Development of a common memory subsystem to lower cost for phone makers
2006	CLEAN	ST, others[g]	Consortium for controlling leakage power in NanoCMOS SoCs
2006		ST, Veredus Laboratories	Team to diagnose avian flu using rapid detection point-of-need lab-on-chip
2006		ST, France Telecom	R&D partnership on secure mobile platform and SIM card IC architectures
2006		ST, Freescale	Broad technology agreement for automotive application

Source: ST documents.
[a]TSMC (Taiwan Semiconductor Manufacturing Company)
[b]Freescale is a subsidiary of Motorola
[c]MIPI is a non-profit corporation that includes handset manufacturers, semiconductor companies, hardware peripheral manufacturers and operating system vendors
[d]CEA (French Atomic Energy Commission), Leti (Laboratory of electronics and information technologies) is a laboratory of the CEA
[e]IMEC is a Belgian researcher institute
[f]HDIC (Shanghai High Definition Digital Innovation Ltd.)
[g]CLEAN is a consortium of 14 European partners composed of semiconductor vendors, EDA vendors, and renowned academic and research centers

of new knowledge within each alliance. On the other hand, it paved the way to the formation of a network-specific shared space (at what we have called the macro-systemic level) that consented to accomplish efficient, effective and rapid information sharing and explicit and general knowledge transfer among the firms embedded in it. In addition, this smoother and faster transfer and sharing of information and knowledge supported the sparking of mutual fertilizations and stimuli within ST's network and the identification of the potentialities associated with establishing both new strong ties at the meso-systemic level and weak ties at the macro-systemic level. The activation of the potentialities above pursued to respond to the opportunities and/or the threats connected to the recurrent changes in the semiconductor industry, and drove the dynamic evolution of ST's network.

Summing up, it is possible to maintain that, during Phase III, among ST and its partners, an intertwined web of dense (at the meso-systemic level) and weak (at the macro-systemic level) ties and, therefore, a complex system of knowledge and capabilities emerged. The interactions occurring among the three different analytical levels within ST's network generated the evolutionary pathways of the ST's network as a whole, of ST's strategic alliances and of ST and its allied firms taken in isolation.

Overview of ST's Network Strategy

The preceding analysis underscores that, in order to achieve and maintain the cutting-edge technological frontier in the semiconductor industry, ST needed to access, develop and integrate a wide set of different (tacit and explicit) knowledge and capabilities, as well as to continuously adapt these sets to the changeable environmental conditions. Accordingly, the aim of fulfilling its cognitive necessities by means of the accomplishment of effective and efficient processes of knowledge transfer and co-production, has driven ST to shape different types and levels of ties with other organizations characterized by idiosyncratic and specific knowledge endowments (i.e., key customers, major suppliers, other semiconductor industry manufacturers, leading universities and research centers worldwide). Consequently, we are in the position to maintain that the nature of the cognitive domains underlying the semiconductor industry crucially affects the structure of ST's network.

It is noteworthy that the pattern of ST's network structure depends, not only on its cognitive domains, but also on deliberate strategic choices taken by ST. On the one hand, ST have chosen not to limit the search for knowledge to locations in which the bulk of technological and market knowledge related to the semiconductor industry is notably concentrated (i.e., Silicon Valley and Japan), but looked for knowledge trapped in pockets of local expertise scattered throughout the world. On the other hand, it has decided to produce integrated and customized system chips, instead of standardized components. This option implied that ST had to mobilize and integrate idiosyncratic and specialized knowledge from a variety of different sources, spread across various sites worldwide.

This twofold strategy differs from the strategies mainly implemented by the other major semiconductor industry manufactures (e.g., Intel) and, by providing state-of-art dedicated solutions to customers in all segments of the global electronic industry, it allowed ST to rapidly turn into one of the key leaders in the global semiconductor industry.

Accordingly, ST have regularly managed to outperform the market since its inception. Commencing in 1987 through 2006, the sales of ST have grown at a compounded annual growth rate (from now on CAGR) of 14% compared to 11% of the semiconductor industry as a whole.[15] In the annual rankings of the worldwide semiconductor companies,[16] starting from the 14th rank in 1987, ST reached the 13th position at the end of the Phase I; the 9th position at the end of the Phase II and the 5th position at the end of the Phase III (see Table 5). More in detail, on the basis of provisional 2006 results published by iSupply, ST at the end of the period of time under scrutiny (the year 2006) were the number one global semiconductor supplier in industrial products, the number two in analog products and the number three in wireless, automotive electronics and NOR Flash. Furthermore, in the course of the third phase the revenues of ST arising from strategic partners have increased from 2,087 million US dollars in 1999 to 4,050 million US dollars in 2006, with a CAGR1999/2006 of 10%.

Table 5. Economic Performance of STMicroelectronics.

	Net Revenues (Million US $)	Rank in Total Semiconductor Market[a]
1987	851.0	14
1991	1,347.0	13
1999	5,056.3	9
2006	9,854.0	5

Sources: Gartner Dataquest Corp., iSuppli Corp.
[a]Ranking by revenues

THE TOYOTA CASE

Toyota Motor Company Ltd. (from now on Toyota) was established in 1937, when Kiichiro Toyoda adapted the knowledge stemming from a detailed field study of Ford's conveyor system to the small production volumes of the nascent Japanese automobile market.

Since its founding, Toyota has been driven by a set of guiding principles aimed at ensuring the best quality and reliability of their products and the respect for people and the environment, on the one hand, and the reduction of the in-process inventory and the production of precise quantities of pre-ordered items with a minimum waste, on the other hand. The lean production philosophy (the so-called 'Toyota way' – Monden, 1998; Fujimoto, 1999; Dyer, 2000) allowed Toyota to rise from the ashes of industrial upheaval in post-war Japan and turn into the world's largest automobile manufacturer.

Commencing its expansion into the American automotive market in the late 1950s, through the decades Toyota have steadily built a solid reputation for high customer service and satisfaction so that their sales figures rival today those of US domestic automakers and have in fact reached in 2006 the most prominent role in the world markets dethroning GM for the first time in over 80 years. In 1984, thanks to a joint venture with GM (called NUMMI), Toyota embarked in the production of vehicles on the US soil. Afterward, in 1988 they decided to establish their first fully owned manufacturing company in Georgetown, Kentucky, which was named 'Toyota Motor Manufacturing Kentucky Inc.' (from now on TMMK).

Interestingly, the transfer of Toyota's assembly plants from Japan to the US entailed the transplant, not only of the production system internal to Toyota's organization, but also of the associated network of supplier relationship (Florida & Kenney, 1993; Adler, Fruin, & Liker, 1999). With the aim of scrutinizing the formation and the evolutionary pathway of the highly idiosyncratic network that tightly connects Toyota to their first-tier suppliers in the Kentucky plant, we have decided to analyze a period of time which covers some 12 years. The period starts with the establishment of the first Toyota plant in the US in 1988 and ends in 2000, when Toyota's network eventually reached its maturity stage. In addition, consistent with the temporal bracketing research strategy, we have decomposed the period under investigation in three relevant temporal phases (i.e., 1988–1991; 1992–1993 and 1994–2000).

Phase I: 1988–1991

When in 1988 Toyota built its first US plant in Georgetown (Kentucky), in order to effectively implement its production system, it needed to find first-tier suppliers able to match the peculiarities that epitomized its highly idiosyncratic production system.

More in detail, the Toyota Production System (from now on TPS) was based on two focal concepts. The first was called '*jidoka*' (that could be loosely translated as 'automation with human touch'), which meant that, when a problem occurred, the equipment stopped immediately, preventing defective products from being produced. The second was the idea of '*just-in-time*', which meant that each process produced only what was needed by the next process in an unremitting flow. The simultaneous use of the above concepts allowed Toyota to manufacture the products required by its customers in the precise quantities desired at a given point in time. Moreover, the search for continuous improvement (the so-called *kaizen*) ensured high-quality products and services that were able to meet a wide variety of customer demands around the world (Cusumano, 1985).

Achieving the pull logic behind the TPS entailed choosing suppliers that shared Toyota's basic idea of combining flexibility and high quality. Precisely, the lack of synchronization between the flows of components from the suppliers and the requests originating from the manufacturing process, as well as the presence of defective components, caused the stop of the production line. Accordingly, Toyota evaluated the aspiring first-tier suppliers on the basis of their availability to take part in long-term supply relationships and to carry out a process of joint growth and continuous learning and improvement based on reciprocal commitment and mutual trust (MacDuffie & Helper, 1997).

Seemingly, Toyota's way of conceptualizing and managing the relationships with its suppliers differed markedly from that of the established US automobile makers, which were traditionally based on price and arm's length relationships. Notwithstanding this situation, Toyota did not take on the characteristics of the American supplier relationships. Rather it created a radically different system typified by a nested network of connections with its suppliers, consistent with its philosophy of continuous learning and relentless improvement (Florida & Kenney, 1993).

To start with, Toyota established with its suppliers a set of bilateral long-term ties with annual price reviews and supported them to adopt the lean production technique bestowing initial high prices. Later on, Toyota attempted to replicate the routines and the learning processes that had been successful in creating an efficient and effective knowledge-sharing network in Japan.

In 1989, Toyota set up a supplier association between its first-tier suppliers, the so-called Bluegrass Automotive Manufacturers Association (BAMA). BAMA was directed to share information and explicit knowledge on production techniques and to promote socialization among the firms participating in it (Dyer & Nobeoka, 2000). The supplier association tried to achieve its goals by means of

(a) *general meetings*, in which, every other month, the suppliers and Toyota gathered and shared information and explicit and general knowledge on the TPS and on market trends;
(b) *committees*, specifically designed to facilitate the transfer of explicit knowledge on critical topics for all the firms in the network, such as inventory cost reduction, quality improvement and safety. Regular committee meetings convened six times each year. Additionally, within the committees training programs and visits to the best practice plants, as well as an annual conference were organized.

Summing up, in the course of Phase I, starting from a set of bilateral relationships, Toyota created a number of spaces of socialization. These spaces were shared by all the suppliers and allowed Toyota to efficiently and effectively transfer information and explicit knowledge associated with the implementation of its production system to all the firms evolved. This situation drove to the creation of a base of shared explicit knowledge among Toyota's nest of suppliers. Moreover, the suppliers participating in BAMA and its activities began to reciprocally interact and, therefore, a connective structure of weak ties began to emerge.

Phase II: 1992–1993

In order to foster the sharing of both tacit and explicit knowledge, in 1992 Toyota established the Toyota Supplier Support Center (TSSC). TSSC was an organizational unit meant to help solve operational problems both at Toyota's and at suppliers' plants. More in detail, TSSC facilitated the transfer of tacit knowledge that resided in Toyota and improved supplier productivity and quality by providing them direct on-site assistance through consulting teams. These consulting teams were built up of experienced Toyota personnel with in-depth knowledge of the principles and practices of the TPS. The durability of the teams at the supplier plant depended on the nature of the problem they had to face and on the learning capabilities of the relevant supplier (Dyer & Hatch, 2006).

It is worth mentioning that TSSC assistance was available to suppliers free of charge, but it entailed the acceptance of a strict norm of reciprocal knowledge sharing. In order to take advantage of the specialized assistance, each supplier had to agree to open up its plants to the other Toyota suppliers. Additionally, as Toyota provided free assistance, training and instruction for suppliers, through the exploitation of which these supplier firms were able to increase their productivity and quality, over time a feeling of indebtedness and trust towards Toyota emerged within the suppliers. In addition, a collection of tacit and explicit knowledge and capabilities on the TPS that were common to Toyota and its suppliers was developed. This situation led to the establishment of strong and intense bilateral connections between Toyota and its suppliers. Moreover, the latter developed awareness of the opportunities associated with the sharing of explicit and tacit knowledge.

Summing up, in the course of Phase II, a set of strong dyadic ties among Toyota and its suppliers forcefully emerged. These ties allowed smoother one-way tacit knowledge transfer from Toyota to its suppliers and paved the way to the reciprocal sharing of knowledge. This set of strong connections was complemented by weak ties that joined the suppliers by means of BAMA and its activities. Nonetheless, the suppliers did not start interacting among themselves in order to reciprocally exchange knowledge under the guidance of a general coordination purpose. Consequently, at the end of this phase, Toyota had not yet generated a complex network of knowledge and capabilities.

Phase III: 1994–2000

During the third phase (1994–2000), the analysis of Toyota's collection of first-tier suppliers permits to observe the emergence of an intertwined web of firms that cooperate by sharing existing knowledge and capabilities as well as generating new knowledge and capabilities. These cooperative activities drove to the formation of a complex system of knowledge and capabilities and fueled its evolution over time.

More in detail, in order to foster the reciprocal sharing of tacit and of explicit knowledge among its suppliers and the co-production of new knowledge, in 1994 Toyota created a web of learning teams, labeled Plant

Development Activity (PDA) core groups. These teams were composed of different and specialized suppliers that shared similar sets of knowledge and capabilities regard the TPS. The creation of a web of learning groups was aimed to support the suppliers which had decided to take part in the program with productivity and quality improvements by means of the activation of specific learning contexts. In accordance with the TSSC, every year they chose a critical theme (associated to the implementation of the TPS) to scrutinize. The in-depth analysis of the predefined topic entailed carrying out a succession of visits to the supplier plants in order to jointly develop proposals for upgrading the problem under investigation. At the end of each year, all the learning groups used to gather at their annual conference to share what they had learned by performing the joint activities.

Over time, the interactions occurring within the learning groups led to the creation among the participating firms of a common set of tacit and explicit knowledge and capabilities, the evolution of a shared language, as well as to the establishment of sentiments of reciprocal commitment and mutual trust. This situation laid the foundations that allowed achieving superior capabilities of (tacit and explicit) knowledge transfer and co-production of new specific knowledge.

In addition, the learning teams were usually being reorganized every three years. This allowed Toyota to generate variety and variability of the knowledge and capabilities that resided within these units. Accordingly, the rotation of the firms belonging to the learning teams was able to overcome the risks associated with the emergence within these groups of myopias that limited the firms' capability to sense the emergence of opportunities or threats connected to changes in the external environment and to react to the changes perceived.

Given the above visualization of Toyota's network of first-tier suppliers, it is possible to maintain that the interactions of the different participating firms over time drove to the emergence of a complex network of knowledge and capabilities. More in detail, the interactions occurred via learning processes activated at both the meso-systemic and the macro-systemic levels. At the meso-systemic level, they developed within the learning teams. At the macro-systemic level, the interconnections occurred within the general BAMA meetings, the supplier association committees, the consulting teams and the annual conference of the learning teams. The intertwined web of weak and strong ties that joined Toyota and its suppliers, allowed the creation of a strong *network identity* (Dyer & Nobeoka, 2000) among the different firms and the incentive to openly share valuable knowledge within the different analytical levels of the network.

Overview of Toyota's Network Strategy

Accordingly, Toyota's complex network of suppliers achieved superior processes of exploitation of the knowledge and capabilities relative to the TPS and of the production knowledge and capabilities of the participating suppliers. Similarly, it permitted to carry out efficient, effective and timely processes of creation of new technical knowledge at the meso-systemic level, in order to continuously improve the productivity and the quality of the network system in accordance with the challenges of the automotive industry. Subsequently, the knowledge generated at the meso-systemic level was shared at the macro-systemic levels sparking mutual fertilization among all the firms embedded in the network. The unremitting tension towards learning and improvement drove the evolutionary dynamics of Toyota's network as a whole, of Toyota themselves and of its first-tier suppliers.

The in-depth analysis performed heretofore underscores that the aim of effectively and efficiently exploiting and exploring the knowledge associated with the implementation and the management of the TPS, drove Toyota to shape different types of ties between the firm and its suppliers, as well as the set of interaction mechanisms and spaces. Accordingly, we are in the position to affirm that the nature of the cognitive domains characterizing the auto industry, in general, and the Toyota production system, in particular, strongly affects the structure of Toyota's network of suppliers.

Interestingly enough, the configuration of the network structure depends not only on the cognitive domains, but also on deliberate choices of Toyota. More in detail, the study of Toyota's transplant to the Kentucky site clearly indicates that Toyota have chosen to not conform to the prevailing US organizational model and the practices associated with supplier relationships. Quite the opposite, they have acted on the environment to create the resources and conditions required to replicate the routines and learning processes that had been successful in creating an efficient and effective knowledge-sharing network in Japan.[17]

In order to creatively respond to the deficiencies of the US environment as regards the delivery and quality requirements of the Japan-like just-in-time system, in the early days of the Georgetown plant Toyota encouraged its first-tier Japanese suppliers to locate in the US, by financing and helping them to set up US branches. Afterwards, however Toyota turned its attention to US-owned suppliers and they worked intensely with them to implant the TPS fully and to accelerate the diffusion of the relevant knowledge. Accordingly, we maintain that the success of the Toyota's transplant was neither natural nor automatic; it hinged on the strategic actions that Toyota have taken to transform existing patterns of inter-firm relationships in the US in light of its cognitive and functional necessities.

It is valuable observing how the creation and evolution of the network that connects Toyota and its first-tier suppliers in Kentucky's Georgetown plant affected the economic performance of TMMK. During the period under scrutiny, the production of the Georgetown factory (see Table 6) has consisted of two models of sedan, i.e. Camry (since 1988) and Avalon (starting in 1994), a model of minivan (i.e., Sierra minivan, starting in 1997) and a variety of power trains (i.e., Axle, 4-cylinder engines, V6 engine starting in 1989).

Should we consider that the two models of sedan, i.e. Camry and Avalon, have produced merely in the Georgetown plant, we can maintain that their sales in the US market portray the economic performance of TMMK. From 1988 to 2000, the sales of Camry in the US have grown at a CAGR of 6.95%. More in detail, the CAGR of the Camry's sales in relation to each of the three phases has been: 9.0% in the first phase; 4.57% in the second phase and 6.48% in the third phase (see Table 7). Interestingly, in the course of the final period examined, Camry has managed to be the first best sold sedan in the US for four years in a row (1997–2000). The production of the Avalon model has taken place only during Phase III of our analysis and its sales have increased from 1994 to 2000 at a CAGR of 48.28% (in Table 7).

Table 6. Production of Toyota Motor Manufacturing, Kentucky, Inc. (TMMK).

	TMMK Vehicle Production (Units Per Year)	TMMK Power Train Production (Units Per Year)
1988	18,527	–[a]
1991	240,242	153,811
1993	284,599	206,382
2000	495,429	479,405

Sources: Toyota.

[a]Power train production starts in 1989 (181 units)

Table 7. Economic Performance of Toyota Motor Manufacturing, Kentucky, Inc. (TMMK).

	Camry Sales in the US (Units Per Year)
1988	187,000
1991	264,000
1993	299,700
2000	448,162
	Avalon Sales in the US (Units Per Year)
1994	6,603
2000	104,078

Sources: Toyota.

DISCUSSION AND CONCLUSION

In the final section, we use the framework entrenched in the complex systems analysis developed in the first part of the chapter as a supporting operational template to determine how closely empirical observations concerning the two cases selected match it; i.e., to assess the extent to which the framework developed contributes to a suitable explanation of the emergence and the evolution of the two inter-firm networks under scrutiny. Using a multiple-case comparative approach, we apply replication logic to draw a few analytical generalizations from the particular set of empirical results obtained from the scrutiny of the cases under investigation. We eventually gather a few implications of the analysis performed for strategy theory and managerial practice.

Our path of investigation is organized as follows. First, we will examine concisely the network dynamics that characterize the two cases at hand. Second, by juxtaposing the cases, we will identify the major commonalities (and differences) that exist between the evolutionary paths and structural configurations of the two networks analyzed. Third, on the basis of the tips obtained, through the use of replication logic we will draw four propositions from our empirical results. These propositions allow to harvest some analytical generalizations regards the fundamental dimensions which define network structures and the dynamic relationships which underlie network structure emergence, evolution and performance. The four propositions represent a starting point for future research regarding the dynamic processes underlying network emergence and evolution. Fourth, we will single out a few implications of the study performed both for forthcoming studies in the network strategy vein and for the intentional management of networks in practice. Lastly, we gather the limitations and conclusions of the chapter. We start by considering ST's complex network.

The Complex Dynamic Network that Links ST with Its Strategic Partners

As previously illustrated, with the purpose of achieving technological dominance in the semiconductor industry and in order to co-generate various types of knowledge, ST started to develop a set of dyadic and multiple relationships with an array of co-aligned actors: (a) key customers, (b) competitors, (c) major suppliers, (d) local leading universities (such as Stanford in Silicon Valley) and (e) other research centers worldwide. Ultimately, ST has established a complex dynamic network, within which the flexible division of work underlying its innovation processes finds fulfilment in a way that allows all partner firms to reach the edge of the knowledge frontier in particular specialized activities. More specifically, the evolutionary path of ST's network depends on its capacity to continuously create, combine, transfer and renew the vast variety of valuable knowledge that characterizes the turbulent industry environments in which its partner firms are embedded. The capacity to nurture a high variety of knowledge bases within the network is assured by the prevalent role of the macro-systemic level, whilst a fundamental role of guidance regards the processes of knowledge combination and transfer is played by ST at the micro-systemic level.

The Complex Dynamic Network that Interconnects Toyota and the Group of Its First-Tier Suppliers

Unlike ST's network, Toyota's one is mainly a *vertical* network of firms that has been built up over time from a set of simple dyadic relationships between each supplier and the core firm (i.e., Toyota) to a complex system of multiple nested ties. Some of these connections (such as the Supplier Association and the Committee Meetings) refer to the macro-systemic level, while others (like the Voluntary Learning Teams and the Supplier Association Committees) relate to the meso-systemic level. The strong role accorded within Toyota's network to highly interconnected ties and their dynamic interactions appear extremely well suited to exploit the existing (tacit and explicit) knowledge inside the network and to foster the relentless co-generation of new knowledge and applications between firms belonging to the same wide embracing meso-systemic level.

Commonalities and Differences between ST's and Toyota's Multilevel Networks

Comparing the results obtained from the empirical study of the ST and Toyota cases, we are in the position to identify the complementary and differential contributions to the evolutionary dynamics of the network that the three analytical levels display in each of the two cases. At a first glance, we could say that, while in Toyota's case we confront 'a complete vertical network', in ST's case we tackle 'a partial vertical network'. This situation may be considered a consequence of the two strikingly different industries in which they operate (e.g., high-tech vs. more established, rapid vs. slow growth rates, industrial market vs. consumer market, and so on). However, if we dig deeper, this contention does not seem sufficiently convincing. In fact, whereas ST's and Toyota's networks seemingly represent the tale of two highly distinctive network worlds, their scrutiny allows to uncover the Pandora's Box that illuminates the path towards a more dynamic exploration of network configuration and architectures. This is actually a tale of one world. By considering the interactions among the three network levels, we can eventually purport that the nature of the cognitive domains underlying, respectively, the semiconductor and automobile industry decisively and similarly affects the architectures of ST's and Toyota's networks (Tables 8 and 9).

Accordingly, the investigation of the emergence and evolution of the network that links ST to its strategic partners allows to underscore that the crucial contribution of the macro-systemic level is to support the identification of the potentialities associated to establishing, modifying, reinforcing or breaking up strong connections at the meso-systemic level. This provision is achieved by means of efficient, effective and rapid information sharing and explicit and general knowledge transfer among the firms participating in the network. The activation of the potentialities which emerge at the macro-level mainly depends on the ST's capacity (at the micro-systemic level) to perceive and exploit them in order to match the challenges recurrently arising in the semiconductor industry. The contribution that the meso-systemic level provides is to overcome the barriers to tacit

Table 8. The Properties of the Complex Systems of Knowledge and Capabilities of ST and Toyota.

	ST's Network	Toyota's Network
Emergent properties	The interactions that take place (in part intentionally and in part spontaneously) among the different firms participating in the ST's network at the meso- and the macro-systemic levels, pave the way to the creation of new knowledge and capabilities as well as the emergence of novel patterns of knowledge transfer and sharing	Over time, the mechanisms and contexts/spaces of interaction deliberately implemented by Toyota at the meso- and the macro-systemic levels of the network are complemented with spontaneous and informal contacts among suppliers aimed at generating new opportunity of knowledge sharing and creation. As a result, the Toyota's network relies less on its focal firm to direct and facilitate the knowledge exploitation and exploration activities
Self organization	In order to render the network's sets of knowledge and capabilities coherent with the rapid innovation pace of the semiconductor industry, the existing alliances are frequently revised and extended in their learning scope (and if it is necessary they are discontinued), as well as other alliances are established with new valuable firms.	Once the Toyota's network has emerged, the composition of the participating firms as well as the mechanisms and contexts/spaces of interaction implemented within the network tend to be stable over time
	As a result, a high dynamics characterizes both the firms participating in the ST's network and the pool of knowledge and capabilities residing within the micro-, meso- and macro-systemic levels	This situation is connected, on the one hand, with the Toyota's choice to develop long-term supply relationships. On the other hand, it is related to the moderate time pressure of innovation of the auto industry and a longer life cycle of automotive products in comparison with the semiconductor ones
Path dependence	The way ST's network has emerged strongly depends on the initial ST's knowledge endowment and the lack of specific technological	The way Toyota's network replication has emerged is deeply affected by the experience, the knowledge and capabilities that

Table 8. (*Continued*)

	ST's Network	Toyota's Network
	assets. This situation pushes ST to search worldwide the knowledge it needs	Toyota has accumulated establishing its network of first-tier suppliers in Japan
	Over time, the accumulated experience and the shared bases of knowledge and capabilities developed at the meso- and the macro-systemic levels, affect network behaviors generating a tendency to look for and co-produce the critical knowledge preferably inside the network	Additionally, the shared experience, the strong network identity and the common bases of knowledge and capabilities developed at the meso- and the macro-systemic levels, influence network behaviors generating a tendency to look for and co-produce the critical knowledge assets mainly inside the network
Organizational closure	The idiosyncratic set of relationships that connect ST and its strategic partners allows us to identify the ST's network per se	The idiosyncratic collection of relationships that connect Toyota and its first-tier American suppliers permits to pinpoint the Toyota's network per se
	This network exists and can be distinguished although, over time, the participating firms can vary and different strategic alliances and learning collaborations follow one another	The sets of suppliers belonging to this network and of its mechanisms and contexts/spaces of interaction were essentially stable over time. Nevertheless, changes in these sets are possible and they do not affect the Toyota's network existence and identity
Thermodynamic openness	The stimuli stemming from environmental dynamics activate changes inside the ST's network, that are geared to secure its survival over time	The stimuli stemming from environmental dynamics activate changes inside the Toyota's network, that are geared to secure its survival over time
Complexity	ST's network is made of idiosyncratic autonomous firms (that are complex subsystems per se). These firms are connected to one another at three interacting levels	The Toyota's network is composed of specialized autonomous suppliers (that are complex subsystems per se). These firms are connected to one another at three interacting levels
	As a result, a thorough scrutiny of the ST's network requires the simultaneous consideration of the three interacting levels	As a result, a thorough scrutiny of the Toyota's network requires the simultaneous consideration of the three interacting levels

Table 8. (*Continued*)

	ST's Network	Toyota's Network
Coevolution	By striving to extract rents from processes of knowledge exploitation and exploration, each firm in the ST's network continuously adapts to the other participating firms and to the external environmental. As each firm adapts, it drives changes in the fitness landscape of the other firms. The interaction of the coupled landscape's changes and the joint adaptations of the single firms constantly generates the dance of coevolution of both the ST's network as a whole and the firms embedded in it	By striving to extract rents from processes of knowledge exploitation and exploration, each firm in the Toyota's network continuously adapts to the other participating firms and to the external environmental. As each firm adapts, it drives changes in the fitness landscape of the other firms. The interaction of the coupled landscape's changes and the joint adaptations of the single firms constantly generates the dance of coevolution of both the Toyota's network as a whole and the firms embedded in it

and idiosyncratic knowledge transfer and to achieve smother and faster processes of knowledge co-generation within shared contexts (i.e., its tight portfolio of strategic alliances) that are characterized by specific and unambiguous learning goals. Also at the meso-systemic level the definition of the learning goals is a critical step that is usually guided by ST's idiosyncratic capabilities (at the micro-systemic level) to seize the opportunities associated to the development and the maintenance of a portfolio of strategic alliances.

In this case, therefore, it becomes apparent that the micro-systemic level (and in particular the focal firm – i.e., ST) plays a crucial role vis-à-vis the macro- and the meso-systemic levels, which continuously take vital lymph from the focal firm's guidance. Consequently, we are in the position to confirm that ST's *micro-level* ability to unremittingly create and recreate its network coherently with the shifting environmental conditions is the key contribution to grasp the network's evolutionary pathway (Fig. 3).

The scrutiny of the complex dynamic network that interconnects Toyota and the group of its first-tier suppliers consents us to pinpoint, within the macro-systemic level, the existence of a collection of different idiosyncratic mechanisms and shared spaces that are aimed at coordinating and integrating Toyota and its suppliers. By way of repeatedly using the

Table 9. A Comparison of the Network Dynamics in the Two Cases Examined.

STMicroelectronics	Toyota Motor Company
Phase 1: 1987–1991	*Phase 1: 1988–1991*
• Emergent meso-level connections with key customers, research institutions and universities	• Creation of spaces of socialization at the macro-systemic level shared by all suppliers
• Objective: integrate a variety of cognitive assets, co-develop new technical tacit and explicit knowledge	• Objective: one-sided transfer of information and explicit knowledge from Toyota to its suppliers
• Characteristics: meso-level connections unrelated to each other	• Characteristics: weak ties at the meso and the macro-systemic levels
Phase 2: 1992–1999	*Phase 2: 1992–1993*
• Building/strengthening a portfolio of strategic alliances with key customers, competitors, major suppliers, universities and research centers	• Emergence of strong dyadic ties among Toyota and its suppliers
• Objective: joint research and technological co-development projects	• Objective: smoother one-way tacit and explicit knowledge transfer from Toyota to its suppliers
• Characteristics: lack of a general coordination purpose of knowledge sharing	• Objective: smoother one-way tacit and explicit knowledge transfer from Toyota to its suppliers
Phase 3: 2000–2006	*Phase 3: 1994–2000*
• Creation of an intertwined web of heterogeneous firms mutually interacting by means of a first-class blend of both weak and strong ties	• Establishment of an intertwined web of specialized suppliers repeatedly interacting within shared contexts and spaces
• Objective: efficient effective and timely processes of knowledge exploitation and exploration	• Objective: cooperate to reciprocally sharing existing knowledge and generating new knowledge
• Characteristics: flexible division of innovative work that allows all partner firms to reach cutting-edge in a particular specialized activity	• Characteristics: strong network identity and high inter-firm motivation to cooperate; incessant tension towards learning and relentless improvement

mechanisms and spaces at hand, strong network *identity* and high inter-firm motivation to cooperate emerge at the macro-systemic level. This condition allows for the achievement of efficient and effective reciprocal sharing, transfer and co-generation of capabilities and knowledge related to the TPS at the meso-level. More in detail, the latter processes take shape under the guidance of a general coordination purpose; i.e., the incessant tension

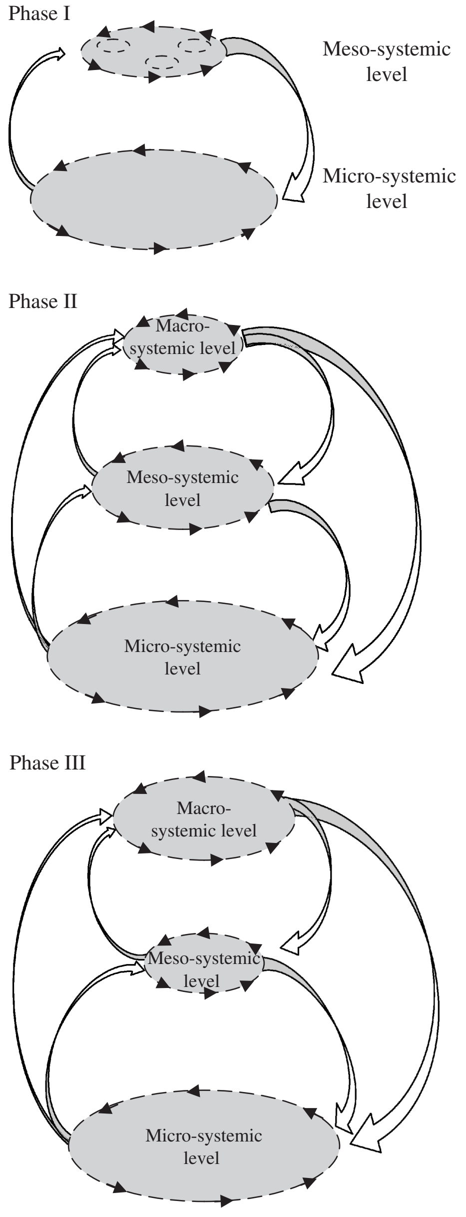

Fig. 3. A Representation of the ST's Multilevel Network along the Three Phases.

towards learning and improvement to meet the challenges in the automotive industry. This tension ensures the coexistence and co-prosperity of the network as a whole and of the single firms participating to it. Additionally, the contribution provided by the meso-systemic level to the evolution of Toyota's network consents effective, efficient and timely co-production of new specific knowledge as well as the transfer of the tacit capabilities and knowledge that reside locally in its suppliers.

It is worth mentioning, that once Toyota's complex network had emerged and the different mechanisms and contexts of interaction at both the meso-systemic and the macro-systemic levels had been implemented (by Toyota), the main contribution of the micro-systemic level to the network's evolutionary path has been to oversee the correct functioning of these mechanisms and contexts. In association to the role of the focal firm, the role of the macro-systemic level is that of creating a strong inter-firm network identity and transferring information and explicit knowledge to and from the external environment and through the network as a whole. It is, however, at the meso-systemic level that the main cognitive processes take place in this network. In Toyota's case, the meso-systemic level is composed of wide embracing contexts that are strongly autonomous vis-à-vis the other levels. Furthermore, the knowledge co-produced within the meso-level is crucial to Toyota's competitive position and steers the evolutionary pathway undertaken by the network as a whole (see Fig. 4).

Consequently, the ability of the mechanisms and spaces implemented at the meso-systemic level to continuously foster learning and improvement within the network vis-à-vis the changes in the automotive industry is the central clue that characterizes the evolutionary pathway of Toyota's network.

On the ground of the former considerations, and applying replication logic to our empirical results, we propose the following four propositions which, rather than targeting to forge immediately testable hypotheses, contain analytical generalizations based on the inductive–deductive reasoning of this study. These propositions seem interesting starting points for further theoretical and empirical research regarding the dynamics underlying the emergence and evolution of inter-firm networks.

> **Proposition 1 – The Fundamental Dimensions of Network Structures in a Dynamic View.** Fully fledged complex networks typically posses both strong and weak ties or, in other terms, they develop a multilevel structure. The weight of strong ties via-à-vis that of weak ties and the role of the focal firms characterize and define the idiosyncratic structure of each network.

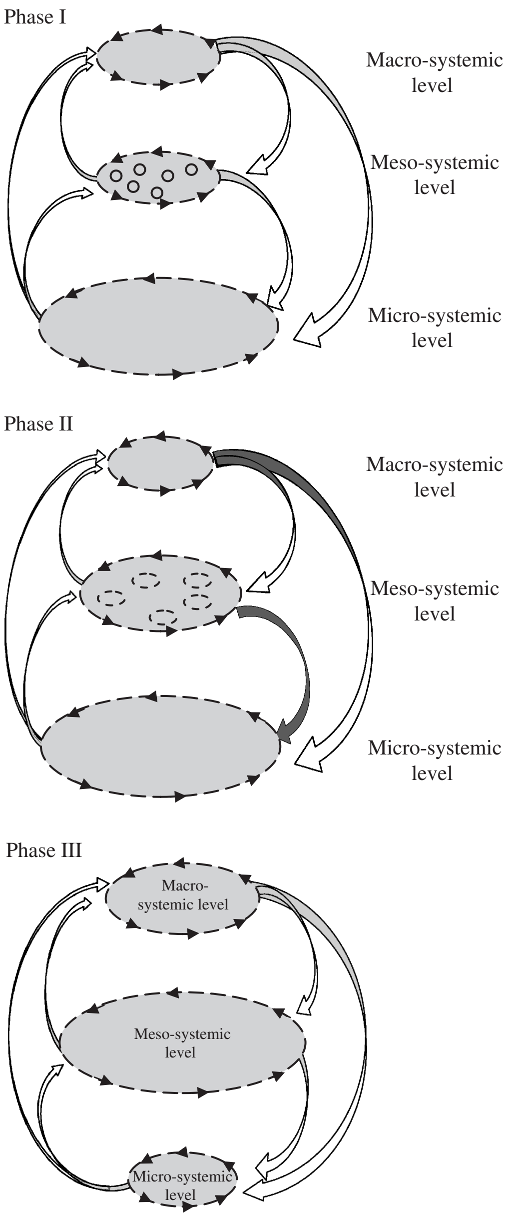

Fig. 4. A Representation of the Toyota's Multilevel Network along the Three Phases.

According to this proposition, fully developed networks will always possess a multilevel structure which includes and is composed of both strong *and* weak ties, as well as single firms at the micro-level. This view breaks away from the dichotomic view of inter-firm relations as being either strong or weak. Though if considered in isolation, single ties between different firms are either strong or weak, by widening the picture in order to consider the complexity of network structures it becomes apparent that firms interconnect and evolve network structures in which both strong and weak ties are present. Also, curtailing the holistic/reductionist dilemma and focusing on the cognitive aspects tied to inter-firm performance and evolution, the integrated complex system/knowledge-based view proposed allows to appreciate and underscore that strong ties and weak ties contribute in fundamentally different ways to the cognitive dynamics that occur within networks – supporting information and explicit knowledge transfer, in the first case, and the sharing of complex tacit knowledge and the co-production of new knowledge, in the second case – and single focal firms may play a more or less relevant role in guiding these cognitive processes.

In order for complete cognitive cycles to be efficiently and effectively carried out, the processes which rest on strong ties, on the one hand, and on weak ties, on the other, must all be present. However, depending on the cognitive goals the network aims towards or is stimulated to point to, the relative importance of one level vis-à-vis the other will change, therefore leading to distinctive morphologies of network structures that foster different knowledge sharing and learning processes and bring each network to develop idiosyncratic cognitive capabilities over time.

Proposition 2 – The Main Variable which Influences Network Structure Configuration. There is a direct correlation between the architectural configuration of inter-firm networks and the cognitive characteristics of the competitive domain in which the network operates. In particular, the relevant trait of the cognitive domain in which the network operates may be intended as the '*cognitive scope*', which must be effectively and efficiently spanned by inter-firm networks (or by single firms) in order to be able to compete successfully in the business environment under consideration.

According to this proposition, network structures, though idiosyncratic to each single inter-firm system, may be rendered intelligible if correlated to the characteristics that define the competitive dynamics and the key strategic factors of the environment in which the network operates. In particular, network structures should be correlated to the *variety* and *complexity* of different knowledge bases and pieces of information that must be spanned, combined and synthesized in order to create the knowledge which is key to compete with success in the industry considered. In essence, the cognitive scope which firms or inter-firm networks must master in industries in which competition rests on radical innovations is larger than the cognitive scope of the processes underlying knowledge production in industries in which competition is based on incremental innovations. In the latter case, in fact, the knowledge bases which must be confronted and brought to new synthesis tend to cover a more focused field but tend to go in greater depth. In this vein, van Liere, Koppius, and Vervest (2008) focus on the network actors' cognitive ability to see the network. This is an antecedent to our framework: actors' ability to see their networks will clearly affect how they perceive the competitive domain.

Thus, networks that operate in industries characterized by high innovation rates and in which competitive dynamics depend on the capacity to develop radical innovations, tend to foster the continuous renovation of the variety of knowledge bases and stimulate creativity through the adoption of structures in which macro-systemic ties are largely prevalent vis-à-vis the meso-systemic level. In order to direct the evolutionary pathway of the network, though, a dominant role must be played by focal firms at the micro-systemic level. It is at this level that variety and opportunity sensing occurs and a fundamental coordination activity is carried out. On the other hand, networks which operate in industries characterized by less turbulent innovation rates and in which competition is based on the capacity to carry out incremental innovations and operational efficiency, foster rapid knowledge exploitation and co-generation of new knowledge towards clearly defined and widely shared goals through dense structures characterized be the strong presence of meso-systemic ties. In this case, once the system is in place, the focal firms' role, at the micro-systemic level, is reduced to that of a monitor, who checks the correct functioning of the institutions created in order to support the processes underlying the systems' cognitive processes and evolutionary path.

> **Proposition 3 – The Causal Antecedents of Network Structure Emergence.** The causal antecedents of network structures are given by the different knowledge bases of the firms belonging to the network and their role in relation to: (a) the cognitive characteristics of the domain in which the network operates; and (b) the (cognitive) aim of the inter-firm system as a whole.

This proposition is logically consequential to the first two stated above and, thus, does not seem to need detailed explanation. Nonetheless, it is important to underscore that this proposition does not lead to consider network structures as exogenously determined. In fact, single participating firms' knowledge bases are exogenously given at the beginning of the networks' formation, but are subsequently endogenously generated through the various phases of the networks' evolution in time also in correspondence to the latter's outcomes and performance. The degree to which each participating firms' knowledge base may be developed is, however, neither exogenous nor completely self determined. Rather, the position each actor occupies within a given network (though initially due to its precedent history and it's knowledge base) will influence the amount and type of knowledge it will be able to absorb and develop and, therefore, the position it will be able to gain in time. Hagedoorn and Frankort (2008) offer support for Proposition 3. Their argument that network embeddedness, which increases over time, leads to a desire to form non-local ties to break this embeddedness and thus alter the structure is germane to the idea that individual network firm's knowledge bases are endogenously generated via the various evolutionary phases. In addition, their contention supports the core claim about the endogeneity of network change we advance in this paper.

> **Proposition 4 – The Dynamics Underlying Network Stability and Instability.** Network structures will tend to be stable as long as they are adequately coherent with the cognitive characteristics of the competitive domain in which the firm operates. Therefore, instability of network structures is a consequence of changes in the cognitive characteristics of the competitive domains in which networks operate.

Once again it seems important to underscore the role of endogenous mechanisms in the evolution of network structures. To this regard, it is to be noted that, while changes in the competitive arena may be a consequence of exogenous factors, networks are themselves players in the competitive field and, as such, contribute (at times even crucially) to determine the changes that occur in the industry in which they operate. The capacity of leading networks to set (or reset) the rules of the competitive game does not, however, exempt them from structural change and instability, which appears an important underresearched area (see also Doreian, 2008 and Amburgey, Al-Laham, Tzabbar, & Aharonson, 2008). This latter consideration may be appreciated by considering the passage from one phase to another in industry life cycles. The passage from a phase of development to one of maturity, for example, may push an inter-firm network towards the adoption of a structure that enhances efficiency (though this may drive out variety), even if the network in consideration is the leading player in the field and has elaborated the dominant design in the industry considered.

Implications and Limitations

On the basis of the conceptual and qualitative analysis performed on ST and Toyota's networks, the chapter bears the seeds for identifying various implications for both strategy theory and practice. The chapter ends with the consideration of the limitations of the inquiry proposed.

Implications for Network Strategy Theory

Early studies in the network approach have observed, either that there are few studies that employ longitudinal data to analyze networks (McPherson, Smith-Lovin, & Cook, 2001) or that most studies of network structure are cross-sectional (Burt, 2000). Other studies echoed that most network research has taken an individual-level perspective missing the opportunity to illuminate the structure of collective action (Salancik, 1995) and that little attention has been given to the evolution of entire networks (Powell et al., 2005).

In the conscious attempt to overcome the limitations mentioned above, the study reported in this chapter focuses on the cognitive aspects tied to network performance and evolution in time. The empirical part of the chapter uses longitudinal data which is aimed to shed light on the processes underlying the evolution of the network as a whole and of its most significant layers and actors. The inherent dynamic nature of this study is due not only to the adoption of the complex system theory as an epistemological base, but more essentially to the notion of knowledge, knowledge sharing and knowledge creation processes underlying it. In essence, the factor that renders change in networks endogenous and that allows to pinpoint the fundamental dimension underlying complex systems dynamics in the case of inter-firm networks is tied to processes of 'real learning' (Hahn, 1973) or, more simply, of knowledge creation.

In our understanding, the theoretical framework elaborated and the results obtained in this study proffer to further developments that may allow us to comprehend the common traits in the current competitive and technological ecosystems and help interpret and guide strategic actor's inter-firm behaviors. In particular, we have singled out three basic implications, which come to disclose avenues for further research that the evolutionary network perspective heretofore outlined has the potential to encourage:

(a) the assessment of the relationships between the cognitive characteristics of the particular domain in which the network operates and the comparative role of strong and weak ties;
(b) a more satisfactory understanding of the network-based determinants of competitive advantage;
(c) the combination of the individual-level perspective with the consideration of the evolution and performance of entire networks.

Firstly, by looking at the comparative vigor of strong and weak ties at the different network levels over time, we have commenced to insinuate the idea that both strong and weak ties are present in all fully fledged complex networks though, depending on the cognitive characteristics of the domain in which the network operates, either one of the other tends to play a more crucial role in the orientation of the networks' evolutionary path. The differential value of such approach rests in the confirmation that the presence of a mix of strong and weak ties is the rule rather than the exception and that there is flexibility in calibrating the weight of the different ties in relation to the network's cognitive requirement.

Second, by means of a qualitative field methodology designed to grasp and explain the origin and structuring over time of inter-firm networks, we have eventually paved the way for a more satisfactory understanding of the network-based determinants of competitive advantage. By visualizing that the loci of competitive advantage rest in the network rather than in the single firm, we have been able to unveil the nature of the cognitive (rent-generating) synergies that emerge from the multiple interactions among the various firms participating to the network. Consistently with this argument, Rowley and Baum (2008) suggest that partnering with direct competitors will alter both the firms' future partnering behavior and their network positions.

Third, the adoption of a multilevel view, which compares and combines coherently individual- and collective-level perspectives, in the analysis of networks allows to draw different actions, strategies and behaviors single firms or groups of firms belonging to networks may follow within a unitary framework of evaluation. This allows to capture reasons underlying firm choices and resulting network structures which may be difficult to comprehend otherwise. The criterion underlying network structures and their evolution is tied to the cognitive objectives and resources of the network. In this sense, the efficiency, efficacy and performance of the network as a whole (or the 'global network view') prevails on the interests of any single participating firm, as from the well-being of the system depends that of each of its participating firm. This multilevel perspective may, for example, help answer questions tied to problems of individual agency or opportunistic behaviors within networks. For example, if actors that span structural holes can use this position to benefit themselves as they trade information, favors etc., why do structural holes remain unfilled? In our view, the distinctive role assigned to the loose macro-level context in the generation of knowledge variety and opportunity creation has proved to be particularly important in the ST case – and, by generalization, we suggest, in all those cases in which competition rests on the capacity to create radical innovations. Individual firms' rent-seeking behaviors which fill the gaps at the macro-level would be detrimental to the innovative capacity of the system as a whole. Dilemmas like the one above can be solved only through the adoption of a dynamic and multilevel approach.

Implications for Network Strategy Practice

Though the idea of network emergence and evolution which may be drawn from this study is certainly not deterministic and allows ample space to emergence and spontaneity, it does consider factors which exert systematic influence on network processes and performance. As such, these factors gain relevance for practice. In fact, by acting on these factors, managers may to some extent intentionally direct and design network structures and processes. In particular, the suggestions which may be gained by this study for the management of networks are:

(a) to link strategy and performance of the network as a whole and of the participating firms to network structure design;
(b) to consider network structure as multilevel and correlate its design to the characteristics of the competitive domain in which it operates, and, in particular, to the cognitive scope which must be spanned to innovate successfully in the domain considered;
(c) to gain a clear comprehension of the role and position of the focal firm itself within the network in each of its evolutionary phases;
(d) to possess a criterion appropriate to assess the stability or instability of network structures and evaluate whether changes (or the absence of changes) are the positive and natural consequence of the evolution of

the network in relation to its external environment, or if rather they are initial signs of inadequacy and crisis that it is necessary to act upon.

Limitations and Conclusion

As regards the limitations of this chapter we first raise the question, inherently inescapable in qualitative research, of the generalizability of issues originating from the comparative study of only two cases of networks, though in depth and extensive. We argue that there is always the necessity to extend the number and range of cases and industries to make the conceptual generalizations more solid and grounded. The study therefore remains exploratory in essence. In this regard, the use of a well-balanced mix of instruments and methodologies, characteristic of comparative static and dynamic analyses, could sustain the relative strength of the generalizability issue. Second, we contend that a considerable extension of this study could entail the longitudinal scrutiny of firms operating in the same industry (i.e., ST and Intel or Toyota and Chrysler). This would allow for the study of network competition which is an intriguing and virtually missing issue in network research.

Lastly, this study is focused entirely on networks whose formation and evolution is based on the need and desire to cooperate in the knowledge sharing and creation processes. However, it must be underscored that not all networks emerge and exist for knowledge-related purposes. Networks formed between venture capitalists, for example, seem to be based on risk-sharing issues rather than knowledge sharing. The framework elaborated in this study is hence of little use in all those cases in which knowledge sharing is not the main underlying rational behind network formation and evolution.

NOTES

1. Nonaka et al. (2000) refer to the contexts of interaction that take place within the firm as *ba*. *Ba* are shared contexts, defined in time and space, within which individuals may relate to one another: (a) sharing information and knowledge; (b) interpreting information and transforming it into knowledge and (c) producing new knowledge through the conversion of meanings and contexts. The latter activities drive to the elaboration of a common language and build a platform of knowledge and competences, which are integrated and shared among the individuals interacting in the *ba* (Nonaka et al., 2000).

2. Organizational closure allows to define the so-called *cognitive dominion* of the network. The cognitive dominion of a complex system is the set of the interactions that the system can embrace without endangering its own organization and without

loosing its own identity. Loosing organizational closure means the disintegration of the system per se (Ceruti, 1994).

3. The adoption of a *holistic* perspective entails analyzing a phenomenon as an interrelated and integrated *unicum* resulting from the interaction of its parts. In this perspective, the properties of the single parts that make the phenomenon become indistinct, on the one hand, and the interactions among the parts and the properties emerging via them become significant on the other.

4. The adoption of a *reductionist* perspective entails analyzing a phenomenon through an approach that consists in a sequence of phases, such as: (a) breaking the phenomenon up into single elements; (b) scrutinizing the single elements in isolation from the other parts; and (c) moving upwards from the properties of the elements to the general properties of the phenomenon. This perspective overlooks identifying the properties that emerge through the interactions between the parts; i.e., the properties that are new as regards to those of the single elements.

5. In each context a variety of mechanisms are arranged in order to achieve the coordination and the integration of the participating firms. These mechanisms consist in the institutionalization of formal and informal rules and norms, incentive systems, joint decision processes for problem solving, negotiation mechanisms, linking-pin roles and units, formal and informal relations of authority, and so on. Each of these mechanisms displays peculiarities which make its adoption more efficient and effective under specific conditions, mainly associated with the goal of the context itself (i.e., the sharing of tacit/explicit knowledge and/or the co-production of tacit/explicit knowledge) (Levanti & Mocciaro Li Destri, 2006).

6. We stress that homophily (Powell et al., 2005) in dense interfirm connections is a risk – not a necessity – and may never actually occur in specific empirical settings. In fact, whereas for the individual strong ties and intense interactions with one or a limited number of other individuals brings to a homogeneity of views which renders isomorphic behaviors highly probable, the same reasoning does not necessarily apply at higher ontological levels and, in particular, at the firm level. It seems possible to imagine that the risk of isomorphism at the firm level depends on the variety of activities it carries out, on the breadth of its fields of activity, as well as its organizational characteristics.

7. According to Mason (1996, pp. 93–94), 'theoretical sampling means selecting groups or categories to study on the basis of their relevance to your research questions, your theoretical position and analytical framework, your analytical experience, and most importantly the explanation or account which you are developing'.

8. It is worth noting that, at its onset, the company was labeled SGS-Thomson.

9. When in 1991 ST implemented their Total Quality Management Program, they chose to adopt the following mission label: 'to offer strategic independence to out partners worldwide as a profitable and viable broad-range semiconductor supplier'.

10. Such as Air Liquide, Applied Materials, ASM Litography, Canon, Hewlett-Packard, KLA – Tencor, LAM Research, MEMC, Schlumberger, Teradyne, Wacker, Co Ware, Synopsis, UMC and Cypress Semiconductors.

11. Such as MEDEA+ (the pan-European program for advanced cooperative research and development in microelectronics technologies and its applications) and

ITEA, which later led to ITEA2 (the pan-European program for advanced pre-competitive R&D for software-intensive systems and services).

12. Such as ENIAC (European Nanoelectronics Initiative Advisory) and ARTEMIS (Advanced Research and Technology for Embedded Intelligence and Systems).

13. Located in the UK (Bristol and Newcastle), Italy (Bologna, Catania, Milan, Pavia and Turin), France (Grenoble, Marseille, Toulouse and Tours), in the US (Carnegie Mellon, Stanford, Princeton, Berkeley, UCSD, and UCLA) and Singapore.

14. Such as CEA, IMEC and France Telecom R&D.

15. Sources: STMicroelectronics and World Semiconductor Trade Statistics (WSTS).

16. The rankings are compiled by Gartner Dataquest Corp. and iSuppli Corp. taking into account the revenues of the semiconductor firms.

17. We are aware that this line of inquiry is at odd with much of the organization theory literature. Conventional organization theory literature suggests that the environment has a strong direct effect on organizations. Accordingly, it is acknowledged that it is generally difficult to transfer organizations between dissimilar environments and as well that, once transferred, organizations tend to take on characteristics of the new environment and/or of organizations with which they interact (Di Maggio & Powell, 1983). In fact, a recent management practice-oriented stream (Adler et al., 1999), used case studies and large-scale surveys to explain in-depth the process of transferring and transforming the best Japanese Management Systems (JMS) by both Japanese and US owned firms. While the most successful of Japanese manufacturing plants in the US rely on home country management techniques, they have had to adapt them to fit US conditions. Similarly, the growing number of US firms that are adopting these techniques to strengthen their own positions face a considerable challenge in transforming them to fit local conditions. But despite the hurdles firms face, the evidence obtained robustly indicates that key aspects of JMS are successful and transferable in the US.

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