

# Networks of Complementarities:

## Complements and Conflicts in Networks Configuration and Evolution

Anna Moretti  
*Phd Candidate in Business*  
*Advanced School of Economics*  
*Università Ca' Foscari Venezia*

Michele Tamma  
*Associate Professor*  
*Department of Business Economics and Management*  
*Università Ca' Foscari Venezia*

### ABSTRACT

In the last decades, research on networks in the field of Social Science has seen a rapid and prolific development, with the consequent birth of a large number of interpretative models, methods of analysis, and theoretical approaches. A consolidated and shared model to analyze their constitution, configuration and evolution seems to be still lacking.

The present paper proposes a model drawn on the economics of complementarities (Milgrom and Roberts 1995) extended in order to face a key problem of inter-organizational relationships, that of Conflict issues (Ogilvie 2007). Interrelationships are read through the double lens of complementarities on the one side, which is mainly related to performance variables, and the Conflict force on the other, which highlights the aspect of social behavior.

The combination of these two constructs aims to open a way to balance structural aspects typical of Network analysis with the peculiarities coming from social behaviors, proposing some transversal lines of research.

# 1 Networks and Complementarity

The construct of *complementarity* has been used in the literature to describe organizational design and organizations' strategy and structure.

The complementarity concept concerns the interrelationships between organizational elements, such as organizational activities (Milgrom and Roberts 1995), strategic choices (Sigglekow 2001, Rivkin 2000), or more generally as elements of organizational design (Rivkin and Sigglekow 2003). This stream of research looks at organizations as complex systems, in which resources, activities, processes are highly interdependent elements that concur in forming the organizational system (Milgrom and Roberts 1990, Levinthal 1997).

Interpreting Networks, constituted by organizations involved in the same value creation process (Ford and MacDowell 1999) through the complementarity conceptual framework allows to deepen some strategic questions. In particular, reading inter-organizational relationships through the lens of complementarities highlights how firms interconnections can result in different value creation processes, in terms of networks' configuration and evolution (successes or failures).

What we want to propose here is that network's interrelations are influenced and affected not only by complementarities, but also by *conflict issues* (Ogilvie 2007), regarding both the internal network's structure and its external relation with the reference environment.

Before to start discussing about complementarities and conflict issues, it seems necessary to put down some basics concepts which we will take for granted in the following sections.

When we use the term "network" we are referring to *organizational structures* which involve several interrelated actors <sup>1</sup> working together on a specific project, or pursuing a common objective, which can be identified by a "collective outcome". The networked organizational structure can be the result of explicit *strategic choices* undertaken by the agents (recalls the concept of strategic alliances), or can be an *emergent structure*, namely the result of structural connections such as parental relationships, or structural connections between internal departments of an organization. Thus, it results that interrelationships can be classified also on the basis of their nature.

- *Interrelationships coming from contracts or agreements*, distinguishable also in two sub-categories: formal and informal. In this case the connections between two agents are the result of their own choices, with different degrees of awareness.
- *Structural interrelationships*: with this category we identify those con-

---

<sup>1</sup>Networks' literature usually considers systems composed by at least three actors. The case of two interrelated subjects, in fact, is object of another branch of the literature regarding dyadic relationships (the *Interaction Approach*), distinguished from networks studies (Ford 1990, Ferrero 1992).

nections between agents that exist independently from the will of the subjects involved.

Whatever the nature of interrelationships or organizational structures, a collective outcome has to be identifiable and recognizable. Obviously the identification of the outcome will strongly depend on the field of study, and starting from the specific area of analysis the concept should be declined. In a business network, the outcome could be identifiable with a single product resulting from the combined activity of all the interconnected subjects (agents, organizations, etc.); in a parental network, the outcome could be identified, just for example, with the knowledge produced and transmitted, or the number of external acquaintances.

Directly related to the concept of collective outcome, is that of *performance*. Depending on the type of collective outcome of the network analyzed, different kinds of performance measurement can be identified. Typically for business networks, whose outcomes are "collective products" (*offering*, Normann and Ramirez 1994), the network's performance can be related, for example, to economic-financial, customer satisfaction, or products' quality measurements; for parental networks, a performance measurement can be identified with the stability of relationships, or with the diffusion of a shared language and symbols. To generalize, we say that the main objective of interrelationships is to set up a *value creation process*, where the value created should be identified in relation with the specific network analyzed.

The value creation process developed within a network is driven and influenced (this is our main hypothesis) by two main forces:

- *Complementarity*, that is the attractive force between complementary resources (in the broader sense- human resources, activities, material resources, knowledge, etc.) belonging to different agents (organizations, individuals, families, etc.), which sees an increase of value of the single shared resource if combined with its complement;
- *Conflict*, that is the force that can express differences among personal interests/goals and power or information asymmetries between different agents.

The two forces, complementarity and conflict, are acting on both internal and external interrelationships, namely connections within the network and its relationships with the external environment.

The combinations of these two lenses to study networks' structure and its evolution and re-configuration has not yet been deeply investigated in the literature.

The complementarity framework, in fact, has been traditionally used to study organizations, where complementary elements were internal activities, strategies or product's elements. Nevertheless, there are some first studies dedicated to complementarities in an inter-organizational context.

A first study dedicated to inter-organizational complementarity linkages is due to Arora and Gambardella (1990), who studied external linkages between small and medium size biotech firms and universities. They demonstrated

through an empirical study for a sample large US, European, and Japanese chemical and pharmaceutical producers, that the strategies of external linkage of the large firms with other parties are complementary to one another. Complementarity here is interpreted as a catalyst for inter-organizational relationships directed to a profound innovation process.

Another example is the work of Lavie (2006) in which the author extends the resource-based view to the inter-organizational ambit, and considers inter-organizational complementarities as a source for creating a valuable resources set for the organization (integrating different firms' resources).

Finally, another approach proposed in this area is that of the co-opetition (Brandenburger and Nalebuff 1996), a mixed strategy composed by collaboration and competition, based on partners' complementarities in the creation of value. Bonel and Rocco (2008) adopted this approach in a case study in which an Italian beverage firm (San Benedetto) was embedded in a complex inter-organizational system built on a dense complementarities network. In particular, they studied changes, due to the implementation of a co-opetition strategy, on single partner's activity system.

In the present work, the application of the complementarities framework follows these examples at the inter-organizational level, where complementary elements are specific resources, activities, capabilities of different organizations.

The starting point is the idea that "a firm's network can be thought of as creating inimitable and non-substitutable value (and constraint) as an inimitable resource by itself, and as a means to access inimitable resources and capabilities" (Gulati, Nohria and Zaheer 2000).

Our interpretation of these "network resources" (Gulati 1999), as above-mentioned, is based not only on the complementarity construct, but also on the conflict one. Then, in a inter-organizational network the nodes are identified as specific organizations' resources or activities, and the arches connecting them, represent complementarity and conflict interconnections. Each network's element (whose value is increased by the presence of elements with which it is connected) is combined with its complements in order to get what we called the collective outcome, which varies depending on network's objectives.

After this brief introduction, in which we have defined the basic concepts to whom we will refer in the present work, the paper is structured as follows: in section 2 the basic model of complementarities is introduced, followed by a presentation of the two main streams of research developed in this field (section 3); section 4 presents two reference concepts for networks studies, those of fit and fitness landscape; section 5 presents the conflict view proposed by Ogilvie (2007) , and the following section 6 presents our proposed framework to study networks through the complementarity lens, extended with the introduction of the conflict view; in the last section 7 we conclude with some remarks and suggestions for future research.

## 2 COMPLEMENTARITY: THE BASIC MODEL

The definition of the construct of complementarity adopted by the majority of contributions in this field (and also that will be adopted in the present paper) is that of *Edgeworth complements*: elements are complements if doing (more of) anyone of them increases the value to doing (more of) the others (Milgrom and Roberts 1995).

The first formal formulation of the Complementarity framework in the field of management and organization is due to Milgrom and Roberts (1990, 1995) who studied the shift to 'modern manufacturing'<sup>2</sup>. The declared purposes of their work were to "give substance to previously elusive notions such as 'fit' or 'systems effects', provide some basis for interpreting claims such as the need for strategy and structure to fit one another, give an approach to modeling such issues formally, clarify some ambiguities and enrich our understanding concerning directions of causation, and also suggest reasons why fit may be hard to achieve and change may be slow, painful, and uncertain" (Milgrom and Roberts 1995).

Using the mathematics of complementarities they provided a way to structure one's thinking about complex strategic and organizational phenomena, allowing to use these ideas in an informal but still rigorous theoretical way.

The starting point is the definition of Edgeworth complements recalled before. The idea is that of positive mixed-partial derivatives of a payoff function, in which the marginal returns to one variable are increasing in the levels of the other variables. From this point of view, returns of each variable are related to that of its complements, and then a variation in the level of one variable is more profitable if the whole system is changed.

In the contribution of Milgrom and Roberts (1990, 1995), the lattice theory, together with the supermodularity concept, provided a mathematical framework able to represent this kind of complementary interactions among variables with a tractable (despite the high number of variables to consider) model, also avoiding some of the main restrictions typical of economic models (payoff function's continuity and differentiability and domain's convexity).

The Lattice Theory is used because constraining a variable (a 'choice  $x$ ') to lie in a sublattice means that increasing the value of some variables never prevents one from increasing the others as well, thus this kind of constraint expresses a sort of technical complementarity.

The other mathematical element used to give substance to complementarity, is the supermodularity of the payoff function (Milgrom and Roberts 1995).

Given a real-valued function  $f$  on a lattice  $X$ , we say that  $f$  is supermodular and its arguments are complements if and only if for any  $x$  and  $y$  in  $X$ ,

$$f(x) - f(x \wedge y) \leq f(x \vee y) - f(y).$$

Taking the case of  $\mathfrak{R}^2$ , the expression above says that a variation in  $f$  from the minimum,  $x \wedge y$ , to  $x$  is less than the variation of a parallel move from  $y$

---

<sup>2</sup>One of the earlier empirical studies on complementarities is the one by Miller (1988), who discusses complementarities between firm's strategies and their environments

to the maximum,  $x \vee y$ . This means that raising one of the variables increases the return to raising the other, than the two variables are complements.

The point is that, mathematically, demonstrating that a certain profit function is supermodular, equals demonstrating that its components are complements.

Both the 1990 and the 1995 works by Milgrom and Roberts propose an optimization model on a profit function with a high number of decision variables (for example products' prices, products' innovations, delivery time, marginal costs of production, etc.), demonstrating its supermodularity and then the complementarity of the organization's decision variables. In particular, the decision variables involved in the model were those typical of Japanese lean production processes, and the model proposed synthesized their impact on organization's performance.

### 3 TWO STREAMS OF RESEARCH

After the affirmation of complementarity construct in the management field, two main streams of research emerged: that of theoretical contributions and that of empirical studies.

On the *theoretical side* several contributions have been developed, mainly focusing on well-defined areas of research, dealing with specific economic and managerial instances (for example, non cooperative games (Vives 1990) and incentive systems (Holmstrom and Milgrom 1994)). An interesting example of application of the complementarity framework is that of Schaefer (1999) in which the objective function represents the optimal partitioning of product's design problem. More recently, Mayer et al. (2004) designed a model based on the concepts of complements and substitutes, which examines the idea present in procurement management that sees supply inspections and supplier plant inspections as substitutes. The work of Csorba (2006) applies the complementarity concept to develop a general model to describe and solve the screening problem faced by a monopolist seller of a network good.

Another important branch within this area is that of the experimental economics, where strategy and organization scholars simulated complementarities among organizational elements to study their effect on performance, innovation, complexity and competitive advantages (Levinthal 1997, Levinthal and Warglien 1999, Ghemawat and Levinthal 2000, Gavetti and Levinthal 2000, Rivkin 2000, Porter and Sigglekow 2001, Sigglekow and Levinthal 2002, Sigglekow 2002).

Within the *empirical area*, two main streams of empirical research have been developed (Scapolan 2004): on one side there are the studies about the adoption rate, namely oriented to analyze complementarities identifying the adoption rate of some organizational elements (new technologies, innovations, practices, etc.) by a significant group of firms (Arora and Gambardella 1990,

Colombo and Mosconi 1995, Abernathy et al. 1995, Whittington et al. 1999, Laursen and Mahnke 2001, Bresnahan et al. 2002); on the other side, there are the studies oriented to measure the complementarities' impacts on the firm performance (Whittington et al. 1999, MacDuffie and Krafcik 1992, Parthasarthy and Sethi 1993, Ichniowski et al. 1997, Ichniowski and Shaw 1999, Massini and Pettigrew 2003).

Thanks to the theoretical and empirical development of the framework proposed by Milgrom and Roberts (1990, 1995), the initial mathematical model now can count to a number of applications and extensions declining it to several managerial issues.

First of all, the concept of *complementary linkages* has been deepened. Complementarity relationships have been identified as a subset of interactions (two elements are said to interact if the value of one element depends on the presence of the other element (Sigglekow 2002)), characterized by the positive mixed partial derivatives of the value function where two elements are involved. Other kinds of interaction very important in the field of management and organization are the substitution relationship and the independence relationship.

In the complementarity framework we can think at these two concepts as different expressions of complementarity, in terms of *intensity*.

Two or more elements (activities) can be defined as **substitutes** if doing (more of) any one of them decreases the returns to doing (more of) the others. Then we can think at substitutability as a complementarity of negative intensity. In mathematical terms, Milgrom and Roberts (1990) expressed the substitutability through the submodular concept:

$$f(x \vee y) - f(y) \leq f(x) - f(x \wedge y).$$

On the other side, two or more elements (activities) can be defined as **independent** if doing (more of) any one of them does not affect the returns to doing (more of) the others.

Thanks to these definitions of substitutes and independent elements, the complementarity framework can describe in terms of *intensity* all possible kinds of interactions among organizational elements or activities. The measure of complementarity linkages in a network of elements can thus be defined in terms of three characterizations of interactions:

- positive intensity represents *complementary elements*;
- negative intensity represents *substitutes*;
- null intensity represents *independent elements*.

The intensity of complementarities is a basic reference point for our model, and in particular for the structural network analysis, as we will see in detail in section 6. In the following section 4, we introduce two other fundamental concepts, those of fit and fitness landscape, that introduce our analysis to the dynamic perspective of networks' evolution, adaptation, re-configuration.

## 4 FIT AND FITNESS LANDSCAPE

Another extension to the basic model regards complementary relationships treated from the point of view of internal and external fit and fitness landscape. This approach focuses on dynamics among organizational elements and between them and the external environment.

The first step is to retrieve the concepts of internal and external fit from the organizational literature: the internal fit measures the coherence of organizational elements system, the external fit measures the coherence between organizational elements system and external environment's features (Sigglekow 2001). The evaluation of "coherence" among all the elements of a system should be again declined on the basis of the field of study and the specific network under analysis.

These two concepts enter the complementarity framework through the *fitness landscape*, which represents in a formal way system dynamics' effects and the relationship between complementarities and fitness levels.

In management studies the fitness landscape is used to describe *complex systems dynamics* (Kauffman 1993), and then it has been applied to study firms' dynamics interpreting organizations as complex systems of interdependent elements, activities, behaviors. It seems straightforward how this kind of analysis can fit a general network organizational context, where the evolution dynamics of the complex system can be interpreted through the interrelationships analysis.

The fitness landscape represents a map of all possible combinations of choices (elements, activities) associated with certain levels of fitness (the NK model proposed by Kauffman in 1993 is the base on which most of these studies are developed). Other applications of the model have been developed to study the relationship between complementarities and performance (not necessarily measured by economic or financial indicators, but can be evaluated as an operative performance, for example, productivity).

The degree of interaction among considered elements determines the geography of the fitness landscape, drawing one or more peaks which correspond to optimal configurations. A peak represents a group of elements with high internal fit (Sigglekow and Levinthal 2002), and its height reflects the coherence between the group of elements and the external environment, namely the external fit.

The fitness landscape measures complementarities among the elements of a system, interpreting interactions all together, for the whole system.



## 5 THE CONFLICT VIEW

Scholars studying strategic alliances and networks formation, sooner or later come up to discuss issues regarding power asymmetries, such as: trust, loss of control, information asymmetries, sharing results, and single contributions' observability (Pisano et al. 1988, Balakrishnan and Koza 1993, Barney and Hansen 1994, Oxley 1997, Dass and Teng 2001).

Regardless the specific type of network under analysis, such problems arising from interrelationships are always present, even though under different shapes. In a business network, for example, power asymmetries among agents need to be transferred in formal agreements, in order to preserve (or promote) trust, essential element for sustaining the collaborative relation.

Starting a collaborative project, in fact, always involves a loss of control over one's own resources, being them material, informative, or knowledge ones. Interrelations mean the opening of one organization's door, often to competitors or other agents present in the market. For every organization (agent, individual, family, etc.), this kind of effort corresponds to a risk, and it needs to be rewarded.

Here arises another problem of collaborative networks: in fact, usually, single contributions are not observable, and the collective outcome need to be shared among all, following certain pre-determined and shared rules.

All the literature about Principal-Agent relationships, and specifically contract theory, used to dedicate a lot of attention to the re-distribution problems, and effort observability.

In networks, these issues are even more strengthened due to the participation of at least three agents in the same kind of relation, which we defined as aimed to reach a collective goal or outcome.

In her recent work, published in 2007, Sheilagh Ogilvie addresses, among the others, some of these questions, proposing the economic approach to institutions called the *conflict view*. In her discussion of the institutions, she proposes this approach based on the idea that "institutions affect not just the efficiency of an economy but also how its resources are distributed; that is, institutions affect both the size of the total economic pie and who gets how big a slice" (Ogilvie 2007).

From this point of view, it seems useful the introduction of the classification proposed by De Wit and Meyer (2004), in which they identify four general dimensions characterizing inter-organizational relationships, and they label them *Relational Factors*:

- *Legitimacy*. With this category they identify those written or unwritten codes of conduct that address participants of a network's behavior;
- *Urgency*. Interrelationships are differently shaped depending on the time pressure applied to them;
- *Frequency*. Past interrelationships and expectations about future ones can influence the present connection, thus relationships can be characterized on the basis of their frequency;

- *Power* is defined as "the ability to influence others' behavior" and, applied to networks, this dimension describes particularly inter-dependences among agents.

The Relational Factors seem to be interrelationships' dimensions useful to describe the aspects related to the conflict issues arising among network's agents.

The conflict issue arises because economic subjects usually disagree about how to share out the slices of the economic pie: and what plays a key-role here are institutions, because typically they affect the size of the pie (influencing efficiency), the type of the pie (who can allocate the inputs) and the distribution of the slices.

The premises of what Ogilvie describes seem perfectly fitting the typical situation of a network structure, in which all the subjects should contribute with some inputs, and the total output depends on the systemic effects of all the inputs, usually making indistinguishable the personal contributions. Thus, rules of access to a network, rules of participation and rules of sharing the outcome really affect all network's results (for example economic performance, durability, stability).

The key point for our purposes in Ogilvie's discussion is the following: "the conflict view is better than its rivals at explaining why institutions often distribute resources to the powerful rather than maximizing aggregate economic welfare. This is because the conflict view explicitly addresses the problem of institutional externalities."

*Institutional externalities* are the ingredient proposed by the conflict view that can be effectively used in our framework for network studies.

## 6 NETWORKS OF COMPLEMENTARITIES

The combination of the two conceptual models, the complementarities one and the conflict view, allows us to analyze networks looking in depth at meaningful dimensions of interrelations, highlighting both the synergies coming from the connection, and also the problems arising with it.

Within this framework, we can think about two possible kinds of networks' analysis, which can also be combined in a unique study: one is the *Structural analysis*, in which the aim is to look at configurations of the value creation process, through the intensity of complementarities and the power relations; the second one is the *Re-configuration analysis*, which aims to explain network's evolution (success, failures, reconfigurations) through the fitness landscape.

In both the approaches, institutional externalities are introduced as a dimension of the complementarity construct: since we are dealing with interrelationships, we need to introduce the tension between the 'positive effect' deriving from collaboration among agents and the 'negative effect' coming

from losing part of control over agents own resources. Three elements of the complementarity framework can be firstly considered as the most plausible links with the conflict view: the intensity of complementarities, the internal and the external fit.

### *6.1. Network's structure analysis*

This kind of analysis aims to provide an insight in the value creation process and the main constructs to which we refer are those of the intensity of complementarities and the relational factors, assumed as main descriptors of the conflict force.

In this approach a network's analysis is aimed to describe interrelationships, in order to understand how the value is created throughout the network. This kind of study would allow on the one side, to identify key-resources and inter-organizational processes which plays a fundamental role for value creation, and, on the other side, which are agents, resources and activities that are part of the network, but do not play a key-role for results achievement.

As previously remarked, in a network we can identify different intensities of complementary interactions among the elements. Let us consider, just for simplicity of explanation, the dual case (relationships between two elements):

- i. If two elements have a positive complementarity, we will talk about complements;
- ii. If two elements have a negative complementarity, we will talk about substitutes;
- iii. If two elements have a null complementarity, we will talk about independent elements.

The introduction of the institutional externalities, explained and described through the relational factors, requires to combine the two constructs chosen as descriptors of interrelationships, namely the complementarities intensity and the conflict force. These two forces can have different, and also opposite, intensity: the complementarity intensity is defined starting from the network's performance, and can be viewed as the correlation between two agents' activities, resources, strategies, in presence of high performance levels <sup>3</sup>; conflict relationships need to be translated by researchers in significant and observable variables for the specific network under study. The Relational Factors (De Wit and Meyer 2004) identifies four general dimensions of relationships within which conflict issues can arise (legitimacy, urgency, frequency and power). In particular, main themes related to these tensions are those of information asymmetry, partial lose of strategic autonomy (control), and uncertainty or

---

<sup>3</sup>Other formalizations are possible in the measurement of complementarities. See for example Grandori and Furnari (2008), where complementarities are measured through Boolean Algebra methods.

disagreement about rules for sharing results: these are just three examples of variables that could be used to measure the conflict force's intensity.

Declined for the empirical application of these theoretical constructs, we can think at data regarding: contractual asymmetries, control policies, forms of punishment for deviations from agreements, or more qualitative information such as correspondence's content, informal long-term relationships, and behaviors expression of trust.

This *static approach*, through the characterization of interrelationships in terms of complementarities intensity and conflict force, allows to represent a Network's structure, designing its specific configuration. Thus, this kind of analysis can also be developed in order to find "optimal configurations" for the analyzed network (in terms of maximum exploitation of complementary interrelations, usually linked to high performance).

The interpretation of emerging optimal configurations can suggest which are the core elements of a network, whose actions can significantly affect the value creation processes, and who are the peripheral elements (or "operational elements"), whose roles are clearly distinct: if the former are the leading agents able to orient, modify and adjust the value creation process, the latter are elements which take a marginal role in the value creation process, and their action can not affect the whole process.

## 6.2. Re-configuration analysis

This perspective is primarily concerned with the network's dynamics, its evolution, in terms of changes in configuration, successes or failures (analyzed with respect to collective output's performance, depending itself on the field of study).

The reference construct from this point of view is that of the fitness landscape, described by Levinthal (1997) as "rugged", since it is usually characterized by peaks of different heights representing all possible local maxima the network can reach.

As previously specified, a peak represents a group of elements with high internal fit (Sigglekow and Levinthal 2002), and its height reflects the coherence between the group of elements and the external environment, then the external fit.

There are two possible ways to interpret and use the concept of *internal fit*: one *a priori*, in which the researcher defines on the basis of a theory (organizational design, or social behaviors, just as examples) which are optimal configurations in terms of intensities of complementarities and conflict relationships, and use them as a point of reference to evaluate his or her network under analysis; the other, *a posteriori*, in which configurations corresponding to high performance levels are analyzed, identifying more recurrent patterns, and taking the emerging optimal configurations as reference point to evaluate all other states' fit.

The *external fit* can be interpreted as the complementarity of a network's

configuration with its social, political, economic environment, namely with all other external agents (and other networks) whose interests can be in conflict with those of the considered network. We can distinguish three possible kind of external conflict relations, with different effects on network's external fit:

- i. *Strong and negative conflict relations* (in terms of direction, namely that the power asymmetry is advantageous for external agents) with other external subjects can have two different results: on the one side, they can lead the network to evolve (for example including or excluding some elements) and to reach another peak of its fitness landscape; on the other side, they can stress the internal relationships and bring networks to failure;
- ii. *Strong and positive conflict relations* (in terms of direction, the advantage is for the network) can make the network reinforce its position within its environment, leaving its positioning on a certain peak unvaried;
- iii. The last possible case is that of *Weak conflict relations* (positive or negative), in which the evolution of the network is mainly driven by internal factors instead of external ones.

The two concepts of fit, internal and external, described by complementarities and conflict intensities, can be used by researchers to describe a network's evolution, identifying micro-states of adaptation and evolution of the interrelationships both among agents and between the network and its environment. In this way, success and failures can be described through a common lens, and the history of a specific network can be read as a path in its fitness landscape.

## 7 CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

In the last decades, research on networks in the field of Social Science has seen a rapid and prolific development, with the consequent birth of a large number of interpretative models, methods of analysis, and theoretical approaches.

Our work follows some of the main constructs that strategy scholars have developed in the last years. In particular, we used as main reference framework that of complementarities, since we believe that it is able to explain the synergistic and attractive dynamic that makes several agents work together.

It is a consolidated and shared concept the fact that the value created by collaborative production is more than the sum of the parts: the complementary framework is able to represent it in a formal way.

It has to be taken into account that Network studies in Social Science are quite different from other applications of this framework especially for their "social nature". Human behavior, in fact, does not follow the deterministic

rules of efficiency driven by perfect rationality. And in particular, when interactions (or interrelationships) are involved, other relational factors influence choices and behaviors of economic agents.

This issue is treated by the Conflict View (Ogilvie 2007), which we introduced to enrich the interrelationships analysis in order to grasp also the peculiar aspect of human interactions that are characterized by issues concerning, among the others, power, legitimacy, time pressure and trust (that we called relational factors, following De Wit and Meyer (2004)).

The conceptual framework here proposed is at its first stage of development. In the paper we presented several research proposals, that would need to be theoretically improved and empirically tested.

The most important weakness of the complementarity approach is its limitation from the predictions' point of view, that comes from the lack of theory able to predict and explain which elements are complementary with which others (Grandori and Furnari 2008). This limitation is translated in several problems in empirical application of the framework, due to the tautology of the complementarity argument: "if what is complementary is defined as what performs best in combinations, then by definition deviations from those high-performing combinations entail lower performance; i.e. the explanatory law is inferred from the very pattern it should explain" (Grandori and Furnari 2008).

However, this field of research appears to be very promising, and new attempts to develop a consolidated empirical approach are emerging in the literature. In particular, the comparative approach (Ragin 1987) developed with the use of the Boolean Algebra seems to be a possible way to test empirically complementary theories that could be developed in network studies. Starting from a theory about which elements are complements (for Complementarities theory building, longitudinal studies about networks' evolution over a long period of time are encouraged), these kinds of logic test are able to verify the complementary hypothesis in empirical applications. Moreover, allowing the use of qualitative variables, this kind of formal approach seems to fit our proposal of interpreting interrelationships both through complementarity and conflict variables.

## REFERENCES

- Abernathy, F., Dunlop, J. T., Hammond, J. and Weil, D. (1995). *The Information Integrated Channel: A Study of the US Apparel Industry in Transition*. Brooking Papers on Economic Activity-Microeconomics, pp. 175-246.
- Arora, A. and Gambardella, A. (1990). *Complementarity and External Linkages: the Strategies of The Large Firms in Biotechnology*. The Journal of Industrial Economics, 38: 361-379.
- Balakrishnan, S. and Koza, M. P. (1993). *Information asymmetry, adverse selection and joint ventures: theory and evidence*. Journal of Economic Behavior and Organization 20(1).
- Barney, J. B. and Hansen M. H. (1994). *Trustworthiness: Can it Be a Source of Competitive Advantage?*. Strategic Management Journal 15(S2): 175-203.
- Bonel, E. and Rocco, E. (2008). *L'architettura della complementarieta'*. Carrocci editore, Roma.
- Brandenburger, A.M. and Nalebuff, B. (1996). *Co-opetition: A Revolution Mindset That Combines Competition and Cooperation... The Game Theory Strategy That's Changing the Game of Business*. Currency.
- Bresnahan, T., Brynjolfsson, E. and Hit, L. M. (2002). *Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence*. Quarterly Journal of Economics 117:339-375.
- Colombo, M. G. and Mosconi, R. (1995). *Complementarity and Cumulative Learning Effects in the Early Diffusion of Multiple Technologies*. The Journal of Industrial Economics, 43(1):13-48.
- Csorba, G. (2006). *Screening contracts in the presence of positive network effects*. International Journal of Industrial Organization, 26:213-226.
- Das, T. K. and Teng, B. (2001). *Trust, Control, and Risk in Strategic Alliances: An Integrated Framework*. Organization Studies, 22(2):251-284.
- De Witt, B. and Meyer, R. (eds.) (2004). *Strategy: Process, Content, Context*. Thomson International Business Press: London.
- Dyer, J. and Singh, H. (1998). *The relational view: cooperative strategy and sources of interorganizational competitive advantage*. Academy of Management Review, 23:660-679.
- Ferrero, G. (1992). *Il marketing relazionale. L'approccio delle scuole nordiche*. Ed. LINT, Trieste.
- Ford, D. (ed.) (1990). *Understanding Business Markets*. Academic Press, London.
- Ford, D. and McDowell, R. (1999). *Managing business relationships by analyzing the effects and value of different actions*. Industrial Marketing Management 28:429-442.

- Gavetti, G. and Levinthal, D. E. (2000). *Looking Forward and Looking Backward: Cognitive and Experiential Search*. *Administrative Science Quarterly*, 45:113-137.
- Ghemawat, P. and Levinthal, D. (2000). *Choice Structures, Business Strategy and Performance: A Generalized NK-Simulation Approach*. Working Paper 00-05, Wharton School.
- Grandori, A. and Furnari, S. (2008). *A Chemistry of Organization: Combinatory Analysis and Design*. *Organization Studies*, 29(3):459-485.
- Gulati, R. (1998). *Alliances and Networks*. *Strategic Management Journal*, 19:293-317.
- Gulati, R. and Gargiulo, M. (1999). *Where do Interorganizational Networks Come From?*. *The American Journal of Sociology*, 104:1439-1493.
- Gulati, R., Nohria, N. and Zaheer, A. (2000). *Strategic Networks*. *Strategic Management Journal*, 21:203-215.
- Holmstrom, B. and Milgrom, R. (1994). *The Firm as an Incentive Systems*. *The American Economic Review*, 84:972-991.
- Holmstrom, B. and Roberts, J. (1998). *The Boundaries of the Firm Revisited*. *The Journal of Economic Perspective*, 12:73-94.
- Horgan, J. and Muhlau, P. (2006). *Human resource systems and employee performance in Ireland and the Netherlands: a test of the complementarity hypothesis*. *International Journal of Human Resource Management*, 17:414-439.
- Ichniowski, C., Shaw, K. and Prennushi, G. (1997). *The Effects of Human Resource Management Practices on Productivity: a Study of Steel Finishing Lines*. *The American Economic Review*, 87:291-313.
- Ichniowski, C. and Shaw, K. (1999). *The effects of human resource management systems on economic performance: An international comparison of US and Japanese plants*. *Management Science*, 45:704-721.
- Kauffman, S. (1993). *Origins of Order: Self-Organization and Selection in Evolution*. Oxford University Press.
- Kolb, B. (2000). *Marketing Cultural Organisations. New Strategies for Attracting Audiences to Classical Music, Dance, Museum, Theater and Opera*, ed. Oak Tree Press.
- Laursen, K. and Mahnke, V. (2001). *Knowledge strategies, firm types, and complementarity in human-resource practices*. *Journal of Management and Governance*, 5(1):1-27.
- Lavie, D. (2006). *The Competitive Advantage of Interconnected Firms: An Extension of the Resource-Based View*. *Academy of Management Review*, 31(3):638-658.
- Levinthal, D. A. (1997). *Adaption on Rugged Landscapes*. *Management Science*, 43:934-950.



Levinthal, D. A. and Warglien, M. (1999). *Landscape Design: Designing for Local Action in Complex Worlds*. *Organization Science*, 10:342-357.

MacDuffie, J. P. and Krafcik, J. F., (1992). *Integrating technology and human resources for high-performance manufacturing: Evidence from the international auto industry*. In: Kochan, Thomas A. and Useem, Michael, (Eds.), 1992. *Transforming organizations*, Oxford University Press, Oxford.

Massini, S., Pettigrew, A. M. (2003). *Complementarities in Organisational Innovation and Performance: empirical evidence from the INNFORM survey*. London: Sage.

Mayer, K. J., Nickerson, J. A. and Owan H. (2004). *Are Supply and Plant Inspections Complements or Substitutes? A Strategic and Operational Assessment of Inspection Practices in Biotechnology*. *Management Science*, 50:1064-1081.

Milgrom, P. and Roberts, J. (1990). *The Economics of Modern Manufacturing: Technology, Strategy and Organization*. *The American Economic Review*, 80:511- 529.

Milgrom, P. and Roberts, J. (1995). *Complementarities and fit. Strategy, structure, and organizational change in manufacturing*. *Journal of Accounting and Economics*, 19:179-208.

Miller, D. (1988). *Relating Porter's business strategies to environment and structure: Analysis and performance implications*. *Academy of Management Journal*, 31:280-308.

Normann, R. and Ramirez, R. (1994). *Designing Interactive Strategy. From Value Chain to Value Constellation*. Chichester, Wiley.

Ogilvie, S. (2007). *Economic Institutions*. *Economic History Review*, 60:649-684.

Oxley, J. E. (1997). *Appropriability hazards and governance in strategic alliances: A transaction cost approach*. *Journal of Law, Economics and Organization*, 13(2):387-409.

Parthasarthy, R. and Sethi, P. S. (1993). *Relating strategy and structure to flexible automation: A test of fit and performance implications*. *Strategic Management Journal*, 14:529-549.

Pettigrew, A. M. and Whittington, R. (2003). *Complementarities in action: Organizational Change and Performance in BP and Unilever 1985-2002*, in Pettigrew, A. M. et al. (2003), "Innovative forms of organizing. International perspectives", Sage Publications, London.

Pisano, G. P., Russo, M. and Teece, D. (1988). *Joint Ventures and Collaborative Arrangements in the Telecommunications Equipment Industry*. In "International Collaborative Ventures in U.S. Manufacturing", ed. David Mowery. Cambridge.

Porter, M. E. (1996). *What is Strategy*. *Harvard Business Review*, nov/dec: 61-78.

- Porter, M. and Siggelkow, N. (2001). *Contextuality within Activity Systems*. Working paper, Harvard Business School, Boston, MA.
- Ragin, C. C. (1987). *The comparative Method. Moving beyond Qualitative and Quantitative Strategies*. University of California Press, Berkley.
- Rivkin, J. W. (2000). *Imitation of Complex Strategies*. *Management Science*, 46:824-844.
- Rivkin, J. W. (2001). *Reproducing Knowledge: Replication without Imitation at moderate complexity*. *Organization Science*, 12:274-293.
- Rivkin, J. W. and Siggelkow, N. (2003). *Balancing Search and Stability: Interdependencies among Elements of Organizational Design*. *Management Science*, 49:290-311.
- Schaefer, s. (1999). *Product Design Partitions with Complementary Components*. *Journal of Economic Behavior and Organization*, 38:311-330.
- Siggelkow, N. (2001). *Change in the Presence of Fit: the Rise, the Fall, and the Renaissance of Liz Caliborne*. *Academy of Management Journal*, 44:838-857.
- Siggelkow, N. (2002). *Evolution toward Fit*. *Administrative Science Quarterly*, 47:125-159.
- Siggelkow, N. and Levinthal, D. A. (2002). *Adapting to Adapt: Sequencing Organizational Structures to Satisfy Conflicting Demands*. Working Paper.
- Topkis, D. M. (1978). *Minimizing a Submodular Function on a Lattice*. *Operations Research*, 26:305-321.
- Vives, X. (1990). *Nash equilibrium with strategic complementarities*. *Journal of Mathematical Economy*, 19:305-321.
- Whittington, R., Pettigrew, A., Peck, S., Fenton, E. and Canyon M. (1999). *Change and Complementarities in the New Competitive Landscape: A European Panel Study, 1992-1996*. *Organization Science*, 10:583-600.
- Zenger, T. R. (2002). *Crafting Internal Hybrids: Complementarities, Common Change Initiatives, and the Team-Based Organization*. *International Journal of Economics of Business*, 9:79-95.