Department of Economics and Statistics
"COGNETTI DE MARTIIS"

Working Paper Series

32/13

INNOVATION PLATFORMS, COMPLEXITY AND THE KNOWLEDGE-INTENSIVE FIRM

PIER PAOLO PATRUCCO

The Department of Economics and Statistics "Cognetti de Martiis" publishes research papers authored by members and guests of the Department and of its research centers. ISSN: 2039-4004

Department of Economics and Statistics "Cognetti de Martiis"
Campus Luigi Einaudi, Lungo Dora Siena 100A, 10153 Torino (Italy)
www.unito.it/de

INNOVATION PLATFORMS, COMPLEXITY AND THE KNOWLEDGE-INTENSIVE FIRM

Pier Paolo Patrucco*
Laboratorio di Economia dell'Innovazione "Franco Momigliano"
Dipartimento di Economia "S. Cognetti de Martiis"
Università di Torino

and

BRICK - Bureau of Research on Innovation, Complexity and Knowledge
Collegio Carlo Alberto, Moncalieri (TO)

1. INTRODUCTION

Economic approaches have evolved in parallel with the firm acquiring an increasing centrality in the dynamics of innovation.

As a matter of fact, only in quite recent years technological advances - long considered an exogenous variable, uncontrollable and not influenced by economic actors - has taken a leading role in the economic literature, so that it is now considered a factor crucial to the competitive positioning of business organizations and the key to growth of modern post-industrial societies (Aghion and Howitt, 1997; Acemoglu, 2008).

The black box of standard economic theory (a production function that transforms inputs into outputs through strategies not investigated with the tools of economists), has been gradually redefining thanks to the insights of different approaches that have taken place in the history of economics. These led to a new understanding of the firm as a learning organization that adopts intentional strategies for the improvement and expansion of its technological capabilities, and ultimately, to strengthen its innovative potential.

While along most of the twentieth century the large company that innovates through vertical integration of R&D, taking advantage of economies of scale and scope, has been regarded as the locus *par excellence* of the production of technological knowledge and innovation, a range of factors have emerged recently - such as the increasing environmental turbulence, the intensification of competition and the increasing complexity of the innovation process. These factors have radically changed the framework and questioned the viability of the vertically integrated model as the more appropriate strategy for the production and coordination of innovation.

The economic literature is in fact showing a new, growing interest in cooperative relations as governance mechanisms for the innovation process, helping to reopen the debate on the virtues of decentralized organization of innovative and productive activities. Innovation studies (e.g., Powell, 1990; Uzzi, 1997; Burt, 2000; Kogut, 2000; Helper, MacDuffie and Sabel, 2000; Ozman, 2009) gathered a growing consensus on the idea that networks are loci of

* corresponding address: Pier Paolo Patrucco, Dipartimento di Economia, Via Po 53 – 10124 Torino; tel. +390116704970; fax. +390116703895; email: pierpaolo.patrucco@unito.it

innovation because they favour interactions between different firms, and support the access to a wide range of complementary technologies and expertise, which becomes an opportunity to recombine existing resources held by individual firms in new knowledge. Combining the flexibility of markets with the visible hand of organization, inter-firm ties reduce the costs of access to disperse and diverse sources of knowledge, which is then considered the main driver of innovation and new knowledge generation.

This chapter traces the main characteristics of the shift in the organization of innovative and knowledge-intensive activities from the vertically integrated R&D model to the distributed and networked model. In particular, it integrates the contributions of the economics of innovation about the importance of knowledge sourced externally as an input in the knowledge production of the firm, with recent insights provided by complexity theory about the importance of changing pattern of interactions among organizations. It highlights the characteristics and virtues of "innovation platform" (Consoli and Patrucco, 2008 and 2010; Gawer, 2009) as a model for the governance of innovation upon which scholarly research is placing a growing interest because it combines some of the advantages of managerial control with the benefits of distributed resources and collective action typical of the network.

2. INNOVATION AS A CLOSED ACTIVITY AND THE DEMISE OF THE VERTICALLY INTEGRATED COMPANY AS LOCUS OF TECHNOLOGICAL KNOWLEDGE

The traditional approach in industrial economics and economics of innovation during the last century supported the argument about the superiority of the Fordist firm, considered the most efficient organizational model for the production of technological innovation because of the benefits stemming from R&D economies of scale and scope, and internal economies of learning (e.g., Penrose, 1959; Chandler, 1990).

This view rested on a model of knowledge production that can be described as 'closed' (Chesbrough, 2003), strongly oriented within the firm, which was based on the principle that successful innovation requires control. According to this view, firms compete on the base of their ability to internally generate, develop, market and appropriate new ideas and new products.

The logic of closed innovation creates a powerful virtuous circle, already identified and described by Schumpeter (1942), based upon the following factors: 1) R&D laboratories internal to the firm producing new knowledge, inventions and discoveries; 2) ideas that have emerged from R&D are filtered and selected, and then developed, leading to the introduction of new products and services; 3) the introduction of new products and services allow the fir achieving higher sales volumes and therefore higher profit margins; 4) extra-profits generate greater availability of resources that firms can invest in new R&D, which in turn leads to new discoveries renewing the virtuous circle.

The strategy of internal R&D accumulation was so efficient in creating economies of scale and scope in the XX century that in many industrial sectors natural monopolies emerged (Chandler, 1990). Using the knowledge produced through their R&D labs, firms increased their ability to develop new products, as well as new properties and applications for existing products, thus benefiting from economies of scope. Economies of scale achieved through extensive R&D provide important entry barriers against potential entrants. Internal R&D was, in this context, a strategic asset that supports a cumulative production of innovations and consequently the strengthening of competitive positions. Only large firms with considerable resources available to invest in large scale and long-term research programs, could in fact compete on such markets for innovation, appropriating at the same – as an effect of the application of intellectual property rights - the greatest parte of the returns stemming from their private R&D investments. The benefits of economies of scale and scope have thus encouraged the growth of a model, typical of the American economy, of proprietary innovation, in which large firms internalize firm-specific R&D and subsequently marketed the results of such knowledge production process (Herrigel and Zeitlin, 2004).

Henry Chesbrough (2003) recently described the pattern of production and organization of knowledge resulting from these dynamics with the image of fortified castles, mostly self-sufficient, set in an arid and poor landscape. Through this metaphor Chesbrough stresses a situation where knowledge is closely protected and developed within the boundaries of firms, while contacts with the external environment (universities and other centers for technological and scientific research) are very infrequent.

For most of the twentieth century this paradigm and the corresponding organization of industrial R&D work efficiently, leading to important discoveries and significant commercial successes.

Since the '90s of the XX century, however, different factors have emerged that led to a rapid and radical transformation of the environment in which firms compete, raising questions about the applicability of this model to the new innovation landscape. First, the increasing environmental turbulence (for instance due to greater instability in prices, the cost of inputs, demand) and the intensification of global competition reduces the effectiveness of managerial planning and command. In other words, it is increasingly difficult for management to predict with a sufficient degree of confidence the evolution of all variables, and is therefore less easy to organize their activities in a coherent and rational way. Secondly, the increased complexity of the innovative dynamics, the acceleration in the process of obsolescence of technology and the significant increase in development costs of innovation reduces the degree of autonomy of enterprises. No company is able to completely dominate all technological and organizational skills and has all the necessary financial resources to develop new knowledge on its own. Finally, and consequently, the firm to search new knowledge to apply into its innovative activity should explore an increasing range of sources. As highlighted for instance by Davenport and Prusak (1998) new and different players are emerging in the innovation system: in addition to public research laboratories and private, large R&D labs, others organization are involved in the production of new knowledge, such as science parks, non-profit centers, university laboratories, start-ups, incubators, as well as supranational research networks (Foray, 2004).
The generation of knowledge is more and more seen as widespread and distributed phenomenon, where firms search, select and integrate external knowledge as a strategic activity. This new context challenges the viability of the closed innovation model to access, develop and commercialize new ideas to market and contribute to undermine the "knowledge monopolies" built in the XX century through centralized R&D (Chesbrough, Vanhaverbeke and West, 2006).

The progressive vanishing out (Langlois, 2004) of the vertically integrated model of R&D implies that the closed and linear logic, which saw innovation as a direct and almost automatic result of internal R&D investment and learning by doing, should be replaced: not only firms should reorganize their innovative strategy in order to benefit from external sources of knowledge and effectively integrate these with that produced internally (Chesbrough, Vanhaverbeke and West, 2006), but entire industries, such as recently is the case of the car sector (Enrietti and Patrucco, 2010), reconfigure their borders and their structures to benefit from expertise and technologies developed elsewhere, for instance in other sectors.

3. COLLECTIVE KNOWLEDGE AND THE THEORY OF COMPLEXITY: OPENING THE BOUNDARIES OF THE FIRM

In this context, the theory of complexity is gaining momentum in the economics of innovation. Complexity theory seems to emerge as a new paradigm able to explain the structural properties and dynamic processes of generation and dissemination of knowledge and innovation. Complexity theory seems to be a useful theoretical framework for understanding the characteristics of the processes of creation and dissemination of knowledge, as well as the characteristics and effects of structures for the coordination of knowledge between different organizations (Antonelli, 2008 and 2011; Lane, Pumain, van der Leew, West, 2009).

Complex systems consist of a set of heterogeneous actors that interact to create new knowledge and organize their activities over time. In particular, within a complex system (Foster, 2005; Hanusch and Pyka, 2007; Barkley-Rosser, 1999):

a) the players are heterogeneous with respect to their skills and the knowledge they possess;

b) each player has access to specific pieces of knowledge, and therefore is characterized by limited cognitive resources, so the creation of new knowledge takes place by trial and error and constant reviews of the conduct;

c) the interaction between the actors involved in the system plays a crucial role as it is through interactions that actors can learn, access new skills and change their behavior, thus creating mutual adaptation processes between individuals and between these and their environment;

d) complex systems are non-decomposable: aggregate dynamics cannot be reduced to micro-behaviours but are instead precisely the result of the interaction between the constituent elements of the system. A change in the composition of the system, i.e. a change in one of its elements, implies a change in the aggregate dynamics.

The evolutionary dynamics of complex systems thus depends on the interactions that occur between individual actors and between micro and macro elements.

Precisely because of this non-decomposability, these systems are: a) inherently dynamic (Consoli and Patrucco, 2010): indeed, the actions of individual agents and the evolution of the environment affect each other, therefore can only be understood in historical perspective; b) characterized by simultaneous changes and reconfigurations at different stages of production that make obsolete the existing know-how, requiring new skills and forcing organizations to acquire and develop new skills (Patrucco, 2010).

Recent advances provided by studies on innovation dynamics can fruitfully enrich this perspective. Indeed, in a complex environment characterized by continuous changes in product features and technologies, radical uncertainty and increasing specialization, individual firms can hardly manage all the technological capabilities needed in the process of generation of new knowledge. Each agent has specific and limited cognitive resources, and therefore dominates specialized modules and complementary technology and knowledge; each firm is therefore unique in relation to its ability to innovate (Cohen and Levinthal, 1989).

In line with the pioneering contribution of Nelson and Winter (1982), who viewed economic change as the product of the actions of actors who possess idiosyncratic skills and abilities, technological knowledge, because of high specialization and differentiation, is therefore characterized by very limited levels of interchangeability and substitutability, and high levels of complementarity.

The portions of knowledge sourced externally may largely differ from those possessed by the firm. The implementation of screening processes and strategies of absorption is a necessary condition for access to existing external knowledge, as well as for the efficient exploitation of externalities in the creation of new knowledge.

This implies that the R&D conducted internally takes on new functions: its role is no longer limited to the production of new knowledge, but includes the identification and understanding of external knowledge available, the selection and integration of the relevant portions with internal knowledge in order to produce more complex combinations of technologies and capabilities.

Some authors (Cohen and Levinthal, 1989 and 1990) have in fact stressed the 'two faces' of R&D and the importance of investing in internal R&D in order to be able to use knowledge sourced externally. It has been suggested, in other words, that the function of R&D is more and more to conduct research that enhances the ability of the firm to identify, assimilate, integrate and ultimately exploit external knowledge, thereby developing absorptive capacity.

In this regard, the process of creating new technological knowledge is increasingly understood as a collective process based on a high degree of complementarity between internal R&D and learning and technological resources acquired externally from other firms (e.g., clients and suppliers, competitors) as well as research organizations (e.g. universities, public labs, technology transfer centers). The integration of the skills and knowledge produced externally requires the implementation of specific strategies for the identification, transaction, acquisition and absorption of external knowledge. Technological communication is therefore a key strategy for the firm to be able to exploit the complementarities between internal and external innovative resources and achieve increasing returns in the innovative process. In this sense, the collective nature of knowledge is not only the effect of a static distribution or sharing of resources, but necessarily requires mutual and intentional participation of different actors in order to take advantage of the interdependencies and the spillovers arising from the well-known indivisibility and complementarity that characterize the knowledge production processes. It is, in conclusion, a process that requires the dynamic coordination between heterogeneous actors, as opposed to the idea of static allocation of resources. Effective distribution of knowledge and opportunities for recombination can in fact take place only if the costs of assimilation of external knowledge are low and with the active communication between agents (Patrucco, 2008).

In short, the production of new knowledge requires the implementation of specific activities aimed at coordinating activities (Richardson, 1972), and thus requires a collective effort aimed at creating and maintaining dynamic complementarity between skills otherwise scattered, fragmentary and incomplete (Consoli and Patrucco, 2008). It is thus a process that takes shape through the interaction between the individual initiatives of specialized and heterogeneous and collective mechanisms that are implemented to align the objectives and incentives of the different actors (Consoli and Patrucco, 2010; Antonelli, 2010).

What was previously described as a process essentially closed, implemented within the boundaries of large firms, is now viewed as an open environment within which firms can create new ideas and knowledge by making their boundaries less defined and subject to continuous redefinition in order to be able to exploit both internal and external technological competencies (Chesbrough, 2003; Chesbrough, Vanhaverbeke and West, 2006).

In this respect a growing empirical evidence (e.g., Love and Roper, 2009; Ozman, 2009; Schilling, 2009) views the single knowledge-intensive and innovative firm as part of a wider network of organizations that collectively operate according to collaborative innovation. It emerges clearly the need for firms to rethink their organizational structures in order to define new models of coordination of knowledge production capable of managing the current complex dynamics of innovation.

4. MODULARITY AND NETWORKS IN THE ORGANIZATION OF KNOWLEDGE AND INNOVATION

The perspective outlined above leads to consider innovation as the result of collaborations developed between various knowledge-intensive organizations.
Networks have been analyzed by an established tradition of scholars from different disciplines with different interests and research approaches, which have in turn focused on different aspects of inter-firm relations. Some authors, for example, adopted a sociological perspective, emphasizing the non-economic basis of social exchange and the importance of interpersonal relationships for cooperation, efficiency production and innovativeness (Granovetter, 1973). Others have instead focused on the institutional network defined as a third alternative with respect to the market and the vertically integrated firm (Williamson, 1975). Other perspectives, have also analyzed the impact of inter-organizational networks on the probability of survival of firms (Uzzi, 1997), the competitive dynamics and organizational performance (Lorenzoni and Lipparini, 1999), the development of new skills and organizational learning process (McEvily and Zaheer, 1999), and last but no least the process of technological innovation (Freeman, 1991).

In particular, in the late twentieth century a broad and intense debate has developed on which is the more efficient organizational form for managing and organizing the processes of knowledge creation and dissemination, and ultimately the organization of innovative activities within complex systems (Consoli Patrucco, 2010).

In order to broaden their knowledge base and coordinate their innovative activity, firms can chose among a continuum of organizational solutions, which can be summarized in three main categories:

a. vertically integrated firms focused on managerial command and authority;
b. modular organizations based on outsourcing and market transactions;
c. hybrid solutions such as collaborative networks between complementary partners.

A wide range of economic contributions offers many insights on the benefits and challenges that each of these solutions entails, and as we have already emphasized, the closed innovation model, based on the vertical integration of R&D and learning has dominated for much of the XX century.

Recently, however, has gained growing consensus among innovation scholars the idea that if companies are not able to develop a sufficient level of innovative capacity by means of internal investments, they can implement hybrid solutions based on different forms of strategic alliances and inter-organizational ties aimed at minimizing the costs of external coordination and maximizing the creative contributions of individual partners. This finding has paved the way for the analysis of various forms (more or less radical) of decentralization, specialization and division of labour in production and innovation.

Thus, a wide stream of studies on the organization of innovation and technological knowledge has turned attention to modular solutions, based on market transactions and outsourcing. In these models, innovative activities and production are not closely integrated and coordination between the two processes takes place through adherence to shared goals and common standards. In these circumstances, the adoption of mechanisms such as standard interfaces ensures the integration of several components designed and made by different and separated units, avoiding specific and strict coordination mechanisms as the interface itself provides an implicit form of communication between all the different units involve in the innovation process (Schilling, 2009).

Studies on modularity are based on some classic contributions of Herbert Simon (e.g., 1962 and 2002) on complexity. Simon describes complex systems as hierarchical entities, i.e. architectures consisting of a plurality of ordered items, where the position of each unit in the architecture determines interactions between the elements[1].

In particular, Simon defines complex systems as loosely coupled systems, i.e. the interactions between different subsystems are much weaker than the interactions within the individual elements of the same subsystem. In other words, in these systems individual elements remain fundamentally separate and independent from each other, and the characteristics and actions of an element can change without causing changes on the properties of other elements of the system (Consoli and Patrucco, 2010). In sum, according to Simon, near-decomposability identified the ultimate property of complex systems.

From this perspective, the literature on modular organizations has deepened the conditions in which they are preferable to integration (Arora, Gambardella and Rullani, 1998, Baldwin and Clark, 1997; Langlois, 2002). For when a system is extended and the connections between elements and subsystems become especially numerous, coordination through an integrated structure is almost impossible. Modular organizations are most efficient in these cases, since by definition they involve breaking the system into subsystems that interact almost independently on the basis of weak connections through common interfaces. In particular, Baldwin and Clark (1997) and Langlois (2002) consider that the organization of production and innovation through modular strategies, i.e. an approach that considers the quasi-

[1] On Simon's legacy on the theory of complexity, modularity and the implications for the theory of the firm, see also the chapter by Andreas Reinstaller on "Modularity and its implications for the theory of the firm" in this book.

decomposable system, represents the most appropriate and efficient way to organize and coordinate complex technologies and systems.

According to this approach, firm, in order to innovate, can decide to adopt an integrated organizational structure or modular according to the characteristics of technology and knowledge they rely upon: the more articulated and interconnected is the knowledge and technological expertise necessary to innovate, the more efficient is to adopt a modular architecture and the use of formal contracts and market transactions, and conversely, the lower the number of elements that must interact to generate innovation, the easier is their coordination through vertical integration of R&D (Chesbrough and Teece, 1996).

The loose coupling strategy, however, has limitations. In particular, activities that require frequent exchanges of tacit knowledge or complex mechanisms also require the presence of more rigid integration than generally a modular organization can produce (Schilling, 2009). If the task requires a form of intense and continuous coordination in time, the development process is conducted more efficiently within an integrated company, which maintains a closer integration between the partners involved.

Moreover, it has been highlighted that complex systems, by definition, are not decomposable into discrete and separate components as stated in the modular approach (Consoli and Patrucco, 2010). A key feature of complex systems relies on the non decomposability of its individual components and subsystems, as changes in the behaviors or characteristics of a given firm - through feedback processes arising from the interaction between the elements - induce transformations in the interconnected organizations belonging to the system. Finally, the empirical evidence shows that, when dealing with decisions related to the organization of innovative activity, firms are not only swinging between purely modular or purely integrated models. Rather, firms are able to use a wide range of inter-organizational solutions in order to combine the advantages of both solutions (Consoli and Patrucco, 2010).

The literature shows a growing emphasis on networks as a place of innovation. Networks facilitate coordination and integration of complementary pieces of knowledge in contexts characterized by complexity, uncertainty and dispersion of knowledge among heterogeneous sources, avoiding the costs and inefficiencies often related to complete integration. Much of the analysis focuses on the nature of the relationship and the roles played by different actors within the networks. The structure of the network received much attention in particular and two opposite configurations emerge: one characterized by strong and redundant ties, and one network characterized by structural holes and weak ties.

According to some authors, for example, networks characterized by strong ties were generally associated with intensive exchange of information, effective mechanisms to transfer tacit knowledge, and mutual trust between partners. Therefore, those links would be more efficient for the exchange and communication of complex knowledge, by enabling the establishment of cooperative behaviours through more efficient and repeated interactions as well as a balanced distribution of power within the network (Coleman, 1990). In contrast, other authors argued that networks characterized by weak connections and structural holes, i.e. firms that act as brokers, directing and coordinating the flow of knowledge between companies or business groups not directly connected with each other, represent the most efficient solutions because of the benefits arising from a (partially) hierarchical organizational form (Burt, 1992).

Empirical evidence shows that both configurations are related to an improvement in innovation performance of firms and Orton and Wick (1990) and Busoni and Principe (2001) tried to reconcile the two streams of literature by developing a somewhat different notion of loosely coupled networks.

Orton and Wick describes inter-firm network based on two parameters: first, distinctiveness, namely the ability to manage and produce a range of complementary technological skills to innovate; second, responsiveness, that is the intentional and active management of inter-organizational structures in order to provide the necessary cohesion of the network and coordinate learning from different and dispersed sources of knowledge.

Under this conceptualization, "if there is responsiveness without distinctiveness, the system is tightly coupled. If there is distinctiveness without responsiveness, the system is decoupled. If there is both distinctiveness and responsiveness, the system is loosely coupled" (Orton and Wick, 1990, p. 205).
It is precisely in this context that the notion of innovation platforms may yield its analytical scope. System integrators that through a hierarchical structure govern and coordinate the interactions between organizations not directly connected to each other characterize innovation platforms. In this sense, companies that act as system integrators are specific forms of structural holes at the center of the flows of different portions of knowledge that are the basis of complex technological innovations.

Innovation platforms are specific organizational forms through which economic agents and their organizations acquire and coordinate innovative capabilities and new knowledge (Patrucco, 2010). The concept of platform expresses the view that innovation occurs when effective partnerships are implemented, based on the convergence of incentives, on the structured complementarity between the skills of a variety of heterogeneous actors, and when a clear direction of mutual interactions emerges, enhancing group cohesion and organization of the intrinsic complexity of the system around a common purpose and shared goals (Antonelli, 2010).

Efficient platforms appear when the various incentives and complementary capabilities of a multiplicity of actors involved in a heterogeneous network are organized and aligned to ensure cohesion and coordination of the network of knowledge exchanges that characterizes the innovation process. As we will argue below, innovation platforms, combining elements of hierarchical coordination and elements of decentralization of skills and innovative activities, are emerging in many areas where innovation is the result of processes and activities carried out collectively.

5. INNOVATION PLATFORMS AS GOVERNANCE FORMS FOR THE ORGANIZATION OF COMPLEX INNOVATION SYSTEMS

As already mentioned, in a context of strong specialization and differentiation economic actors possess portions of idiosyncratic and highly specific knowledge. This implies a high degree of complementarity between the technological expertise and a low degree of substitutability, and consequently some difficulty and stickiness (von Hippel, 1994) to exchange knowledge between firms. In this context, it is essential for the individual firm to be able to expand the range of internal portions through the accessing to and integration of external knowledge (Consoli and Patrucco, 2010). The crucial problem for economic analysis therefore becomes to understand how firms can acquire and coordinate new technological knowledge.

In this context, innovation platforms are receiving much attention. The empirical evidence shows the emergence of this type of coordination structures in many areas where innovation and production of new knowledge are the result of the integration of complementary and heterogeneous skills, widespread and dispersed among specialized actors (such as the automotive, banking, electronics, software). One of the key points of the logic behind the creation of platforms is in fact maximize the variety of contributions from heterogeneous sources of knowledge, although accompanied by the scope of coherence and consistency through a hierarchical structure (Consoli and Patrucco, 2010).

Innovation platforms in this sense represent a significant organizational innovation alternative to the integrated firm, the market and the network themselves. Rather, platforms constitute a new and specific form of governance of knowledge that emerges as a result of the dynamics of complex systems (Consoli and Patrucco, 2010). In particular, they can be defined as a hierarchical network, that is, networks in which interactions do not emerge and evolve spontaneously, as for instance in the traditional literature on industrial districts, or as suggested by the theory of complexity, but where the key nodes (organizations) exert an effect on directing the behavior of other actors, influencing and leading such behavior and the evolution of the system as a whole (Consoli and Patrucco, 2008).

The distinctive feature of these organizational forms is the active search for the exploitation of complementarity between different activities. In other words, innovation platforms are structured and designed to achieve precise and specific innovative targets. In this context, as mentioned above, play their key role the platform leaders.

Given the increasing spread of this phenomenon in different industries, platforms have recently been the object of numerous studies of the economics and management of innovation (see also for a review of this literature, Gawer and Cusumano, 2002; Gawer, 2009a; Gawer, 2009b; Consoli and Patrucco, 2008; Patrucco, 2010). It is now recognized that the emergence of platforms profoundly impacts on industrial dynamics, creating new forms of competition and paving the way for the creation of new cooperative relations and inter-organizational innovation processes (Gawer, 2009a).

Interestingly, despite the notion of platform has been used and tested in different fields of scholarly research, the meaning of the term varies considerably among different research areas (Gawer, 2009b).

It is therefore useful to refer to the typology recently elaborated by Annabelle Gawer (2009b), which identifies three basic types of platforms, characterized by several features related to the context in which they develop and the objectives for which they are created.

- *Internal platforms*: are basically product platforms that develop within the boundaries of the firm. In this sense, these can be defined as organizations to produce goods designed for specific market, though designed to be easily modified and transformed through the addition, replacement or removal of certain components or characteristics (Gawer, 2009b). In other words consist of a set of interfaces designed intentionally to produce a common structure from which can be efficiently developed a bundle of products. The advantages of this platform lies in a reduction of fixed costs, greater efficiency and flexibility in developing new products through reuse of common parts, and particularly the capacity to produce a wide range of products. Furthermore, internal platforms promote economies of scope across different products, thus reducing the exploration of new technological solutions, particularly long especially in the case of complex products (as evidenced by the wide use of such platforms in the automotive or aerospace industries). The literature on product platforms then implicitly assumes that the firm (usually identified with a large manufacturing company that handles both in-house design and production) is able to determine in advance the ultimate use of the product, and therefore has the required expertise for the development of new goods, services or technologies. This approach does not take into account the problem of access and integration of knowledge and innovative capabilities of enterprises and organizations.

- *Supply chain platforms:* are made up of a set of subsystems and interfaces that form a common structure from which various partners along the supply chain can develop and produce a range of products. These are, in other words, product platforms shared between different providers or between providers and the firm that integrates the final complex products. In short, while the architecture remains almost unchanged compared to product platforms (the basic design rules are the systematic reuse of modular components and stability of the system architecture), the participation of different economic actors introduces inter-organizational specific collaborative and competitive dynamics.

- *Industry platforms*: the products, services or technologies are developed by one or more firms, on the basis of which a large number of other organizations (loosely coupled within the so-called industrial ecosystem) produce and develop complementary products, services or technologies. A clear difference from the supply chain platforms is that, in the case of industry platforms, firms that develop complementary products are not necessarily belonging to the same supply chain. Moreover, this type of platform is characterized by the presence of leading firms that introduce innovation in the industry through the coordination and integration of products and components developed separately and independently from each other. The different contributions about industry platforms have shown that such structures affect the competitive dynamics and the level of innovativeness of the sectors in which they are implemented. Indeed, the emergence of a platform can change the balance of power between assemblers and suppliers or can even damage leadership positions. At the same time, these types of platform increase the degree of innovation in complementary products and services. The greater the degree of innovation in components, the greater the value created for the platform and its users through direct and indirect network effects. Regarding the design rules, industry platforms share with other categories previously described the stability of architecture, which represents a milestone in every platform. However the latter category has some important differences compared to previous ones. Indeed, the logic of design in this case is reversed. In other words, there is not a firm that is configured as master designer (and that in previous cases always coincided with the final assembler), but rather there exist one or more core components that are part of a larger modular structure, and the result of their final integration is unknown or only partially known *ex ante*. In fact, within industry platforms the precise use and characteristics of the final product is not predetermined. This means that the fundamental design rules for these platforms is the principle that the interfaces must allow the incorporation of new components, as well as the innovation of existing components.

The different characteristics and types shown above demonstrate that platforms may take actually different forms. However, some contributions have also highlighted the key features of platforms.

First, all platforms are based on the reuse and sharing of some core components in complex products or production systems (Baldwin and Woodard, 2009). Thus, for example, Meyer and Lehnerd (1997) describe product platforms as a set of components or modules from which can be effectively created a new line of products. In a broader sense, Robertson and Ulrich (1998) describe them as the set of assets (components, processes and knowledge) shared by a set of products.

One of the most useful definitions for the purposes of this discussion, however, has been provided by Bresnahan and Greenstein (1999), who describe the industry platform as "a bundle of standard components around which buyers and sellers coordinate efforts " (Bresnahan and Greenstein, 1999, p. 4).

The rationale behind the re-use of some core components is simple but powerful (Baldwin and Woodard, 2009): the fact that some elements are fixed implies that it is often possible to achieve economies of scale by increasing production volumes, spread fixed costs over several product classes and use more efficiently complementary assets (such as distribution channels and support services). At the same time, firms can create economies of scope at the system level by reducing development costs of variants of products aimed at different target market.

Baldwin and Woodard (2009) then identify the essential feature of all platforms in their architecture. It is the system architecture to allow obsolete components to be removed and new ones to be involved in setting up new products for specific market niches. It can be argued, therefore, that at the architectural level all types of platforms are equivalent (Baldwin and Woodard, 2009), insofar as all platforms are characterized by specific modularity. The overall innovation system is divided into two sets of components: the first characterized by low variability and high reusability, the other by high variability and low reusability. The former are exactly the platform, while the others are additional elements and complements. Interoperability is made possible by the creation of interfaces or design rules that specify the mode of interaction between the two elements of the overall innovation process.

The components of the platform are therefore essentially three:

- a core set of components that remain relatively stable over time;
- a set of complementary components characterized by high diversity and high rates of change over time;
- interfaces that represent the set of rules - or design rules - which govern the relationships between components and allow the core and complementary elements to operate as a coherent system. In particular, interfaces specify the direction and nature of relationships between system elements, and are therefore also stable and long lasting.

While the core components can evolve over time, under competitive pressure or in response to changes in the external environment, interfaces that govern the interaction between the components represent a stable element, which does not change over time as they are based on identity and internal coherence of the platform. The combination of stability and variability - that allows the creation of novelty without leading to the redefinition of the entire system as a whole or the construction of a new system from the beginning - it is achieved through these tools.

The existence of stable, yet versatile, interfaces creates a fundamental property of the platforms, which makes them a particularly useful tool in a complex and constantly changing environment: the ability to evolve. In other words, the platforms are able to evolve, adapting to unexpected changes in the external environment (Baldwin and Woodard, 2009). It has been already mentioned that the architecture divides the system into core components, relatively stable, and peripheral components, variables. The principle of reusing core components reduces the cost of innovation at the systemic level. This means that, under this approach, to generate a new product or to meet changing external environment does not require a radical change in the whole system, but simply a change in the peripherals components. Consequently, platforms as a whole can be adapted at relatively low cost without losing or changing their identity and their own design incorporation.

For these reasons it has been argued that innovation platforms are particularly advantageous when technological developments are uncertain, and the system must adapt to unpredictable changes (Baldwin and Woodard, 2009). In particular, major contributions (Meyer and Lehnerd, 1997, Robertson and Ulrich, 1998, Bresnahan and Greenstein, 1999, Baldwin and Clark, 2000; Gawer and Cusumano, 2002; Gawer, 2009th; Gawer, 2009b; Baldwin Woodard, 2009) identify platforms as a means of coordination particularly efficient for the organization of innovative activities in the case of modular technology, managed through loosely coupled structures, i.e. that allow the insertion or removal of some peripheral components without affecting the architecture of the system as a whole. According to these approaches modularity plays a fundamental role in the creation of platforms, as the decomposition of complex products or technologies into simpler forms can establish standardized interfaces for components, which in turn enables and facilitates the introduction of new modules (Baldwin and Clark, 2000).

However, as we have already stressed, according to the central assumption of complexity theory, systems are complex precisely because are irreducible to their constituent elements, which are interconnected with each other and only to a very limited extent interchangeable and replaceable. In other words, their evolution is determined by the interaction between a plurality of heterogeneous actors and in which the conduct and actions of an element can affect and change the trend and characteristics of other elements as well as the system as a whole (Consoli and Patrucco, 2010).

Those approaches that consider innovation as a collective process stressed that the development of a new technology is the result of a sequence of actions and user-producer relations brought forward in time by a number of additional actors. The rate and direction of the innovative process, therefore, are not predetermined but they can develop at any time according to a range of options, precisely affected by the relationships between actors and their behaviors.

The exclusion or inclusion of actors with different profiles in terms of skills and abilities, with different and idiosyncratic innovative capabilities, change the behavior of the platform strategy, as well as the objectives and actions that can be achieved through a distributed organization of innovation.

In this perspective, platform leaders play a crucial role. Concepts such as 'architectural knowledge' (Henderson and Clark, 1990) or 'architectural capability' (Jacobides, 2006) have been introduced precisely to describe the ability, owned by the network leader to coordinate and direct the work of complex organizations, and more precisely to combine elements of traditional integrated models (such as authority and control), with characteristics of modularity (as a sufficient degree of openness) to select the firms, skills and knowledge relevant to be included in the network (Gawer, 2009b; Consoli Patrucco, 2010).

Only intentional convergence and alignment of the different incentives and capabilities to common goals and strategies can shape the direction and speed the innovation process. Innovation is thus the product of endogenous coalitions organized around specific platforms (Antonelli, 2010). The specialization requires a wider knowledge base of system integrators to understand and integrate knowledge and innovations from outside and to manage network components and subsystems outsourced. Therefore, the core competencies of the company acting as system integrators include the ability to govern the processes by which innovation is produced and shared collectively.

In this context the concept of innovation platforms as specific forms of coalitions is emerging (Consoli and Patrucco, 2010). In other words, hierarchical networks, focusing on key firms whose strategic conduct directs and coordinates the behaviors and contributions of a number of parties, appears as the most appropriate form - as opposed to extreme solutions such as vertical integration or modularization of organizational structures – for the management of innovative activities in complex environments.

6. CONCLUDING REMARKS

According to the seminal work by David Teece (1984), a radical or “systemic” innovation can be defined as a new product or technology that requires changes in different and connected elements of the system in which it will be placed, in contrast to “autonomous” innovations that easily fit into the system already existing without calling for consequent, diffused and simultaneous changes elsewhere in the system. Following this contribution, in the literature about the organization and management of innovation, it is often presumed that the more radical or “systemic”, to use Teece’s words, is innovation, the more appropriate and efficient is vertical integration and the coordination of the change within a single organization.

Instead, the contributions on innovation platforms points to the fact that, from both a conceptual and practical viewpoint, the crucial element that makes more desirable an distributed innovation model rather than vertical integration is not necessary the novelty of the technology or the knowledge being implemented, but rather how closely complementary are the activities and capabilities required to innovate. Scholars interested in both the governance of innovation and the theory of the firm would do well to rediscover the classical work of G. B. Richardson (1972) about the “organisation of industry” (see also Langlois and Foss, 1999; Langlois, 2003). Richardson argued that systemic productive and technological capabilities are closely related or complementary, and require close coordination and reciprocal adaptation to ensure the success of the innovation. When the firm is not able to acquire and organize such capabilities on its own, some intermediate forms of coordination may emerge, such as licensing, equity agreement and joint venture. More generally, in these cases the governance of innovation relies upon forms of collaboration and networking.

This seems precisely to be the case of innovation platforms, where large coalitions have been implemented with the scope of learning and acquiring technological and productive competencies sourced externally. Yet, some elements of a hierarchy characterize such models since some directedness is required in order to both guarantee the cohesion of the network and the convergence of the complex system of goals, incentives and interactions that characterizes such articulated innovation processes.

REFERENCES

Acemoglu, D. (2008), *Introduction to Modern Economic Growth*, Princeton University Press, Princeton.

Aghion, P., Howitt, P. (1997), *Endogeous Growth Theory*, MIT Press, Cambridge, MA.

Antonelli, C. (2008), *Localized Technological Change: Towards the Economics of Complexity*, Routledge, London.

Antonelli C. (2010), From population thinking to organization thinking: Coalitions for innovation*, Regional Studies* 44 (4), 513-518.

Antonelli, C. (2011), The economic complexity of technological change: An introductory frame, in Antonelli C. (ed.), *The System Dynamics of Technological Change*, Edward Elgar, Cheltenham, forthcoming..

Arora, A., Gambardella, A., Rullani, E. (1998), Division of labour and the locus of inventive activity, *Journal of Management and Governance* 1 (1), 123-140.

Baldwin C. Y., Woodard C. J. (2009), The architecture of platforms: a unified view, in Gawer A. (ed.), *Platforms, Markets and Innovation*, Edward Elgar, Cheltenham.

Baldwin C. Y., Clark K. B. (1997), Managing in an age of modularity, *Harvard Business Review* sett.-ott., 84-93

Baldwin C. Y., Clark K. B. (2000), *Design Rules: The Power of Modularity, vol. I*, MIT Press, Cambridge, MA.

Barkley-Rosser Jr., J. (1999) On the complexities of complex economic systems, *Journal of Economic Perspectives* 13 (4), 169-192.

Bresnahan T. F., Greenstein S. (1999), Technological competition and the structure of computer industry, *Journal of Industrial Economics* 47 (1), 1-40

Brusoni S., Prencipe A., Design rules for platform leaders, in Gawer A. (ed.), *Platforms, Markets and Innovation*, Edward Elgar, Cheltenham.

Burt R. S. (1992), *Structural Holes: The Social Structure of Competition*, Harvard University Press, Cambridge, MA.

Burt, R. (2000), The network structure of social capital, in S. I. Sutton and B. M. Staw (eds.) *Research in Organizational Behaviour*, JAI Press, Greenwich.

Chandler A. D. (1990), *Scale and Scope: The Dynamics of Industrial Capitalism*, Belknap Press, Cambridge.

Chesbrough H. W. (2003), *Open Innovation: The New Imperative for Creating and Profiting from Technology*, Harvard Business School Press, Cambridge, MA.

Chesbrough H. W., Vanhaverbeke W. and West J. (eds) (2006), *Open Innovation: Researching a New Paradigm*, Oxford University Press, Oxford.

Chesbrough, H. W., Teece, D. J. (1996), When is virtual virtuous? Organizing for Innovation, *Harvard Business Review* 74 (1), 65-73.

Cohen W., Levinthal D. (1989), Innovation and learning: The two faces of R&D, *Economic Journal* 99 (397), 569-596.

Cohen, W. M. and Levinthal, D.A. (1990), Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly* 35 (1), 128-152.

Coleman J. (1990), *The Foundations of Social Theory*, Harvard University Press, Cambridge, MA.

Consoli D., Patrucco P. P. (2008), Innovation platforms and the governance of knowledge: evidence from Italy and the UK, *Economics of Innovation and New Technology* 17 (7), 699-716.

Consoli D., Patrucco P. P. (2010), Complexity and the coordination of technological knowledge: the case of innovation platforms, in Antonelli C. (ed.), *The System Dynamics of Technological Change*, Edward Elgar, Cheltenham, forthcoming.

Davenport T. H., Prusak L. (1998), *Working Knowledge: Managing What Your Organization Knows*, Harvard Business School Press, Cambridge, MA.

Enrietti A., Patrucco P. P. (2010), Open innovation and systemic reconfiguration in the car industry: the case of electric vehicles, LEI & BRICK WP 08/2010.

Foster J. (2005), From simplistic to complex systems in economics, *Cambridge Journal of Economics* 29 (6), 873–892.

Freeman C. (1991), Networks of innovators: A synthesis of research issues, *Research Policy* 20 (5), 499-514

Foray, D. (2004), *The Economics of Knowledge*, MIT Press, Cambridge, MA.

Gawer A. (2009a), Platforms, markets and innovation: An introduction, in Gawer A. (ed), *Platforms, Markets and Innovation*, Edward Elgar, Cheltenham.

Gawer A. (2009b), Platform dynamics and strategies: from product to services, in Gawer A. (ed), Platforms, Markets And Innovation, Edward Elgar, Cheltenham.

Gawer A., Cusumano M.A. (2002), *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*, Harvard Business School Press, Cambridge, MA.

Granovetter M. (1973), The strength of weak ties, *American Journal of Sociology* 78, 1360-80.

Granovetter M. (1985), Economic action and social structure: The problem of embeddedness, *American Journal of Sociology* 91(3), 481-510.

Hanusch, H. and Pyka, A. (2007) Principles of Neo-Schumpeterian economics, *Cambridge Journal of Economics* 31 (2), 275-289.

Helper, S., MacDuffie, J. P. and Sabel, C. (2000), Pragmatic collaborations: Advancing knowledge while controlling opportunism, *Industrial and Corporate Change* 9 (3), 443-488.

Herrigel, G., Zeitlin, J. (eds.) 2004, *Americanization and Its Limits: Reworking US Technology and Management in Postwar Europe and Japan*, Oxford University Press, Oxford.

Kogut, B., Zander, U. (1992), Knowledge of the firm, combinative capabilities, and the replication of technology, *Organization Science* 3 (3), 383-397.

Kogut, B. (2000), The network as knowledge: generative rules and the emergence of structure, *Strategic Management Journal* 21 (3), 405-425.

Henderson R.M., Clark K.B. (1990), Architectural innovation: the reconfiguration of existing systems and the failure of established firms, *Administrative Science Quarterly* 35, 9-30.

Jacobides M. G. (2006), The architecture and design of organizational capabilities, *Industrial and Corporate Change* 15 (1), 151-171.

Lane, D., Pumain, D., van der Leew, S. and West, G. (eds.) (2009), *Complexity Perspectives on Innovation and Social Change*, Springer, Berlin.

Langlois, R. N. (2004), Chandler in a larger frame: markets, transaction costs, and organizational form in history, *Enterprise & Society* 5 (3), 355-375.

Langlois R. N. (2002), Modularity in technology and organization, *Journal of Economic Behavior & Organization*, 49 (1), 19-37.

Langlois R. N., Robertson P. L. (1995), Innovation, networks, and vertical integration, *Research Policy* 24 (4), 543-562.

Lorenzoni G., Lipparini A. (1999), The leveraging of interfirm relationships as a distinctive organizational capability: a longitudinal study, *Strategic Management Journal* 20 (4), 317-338.

Love, J. H., Roper, S. (2009), Organizing the innovation process: complementarities in innovation networking, *Industry and Innovation* 16 (3), 273-290.

McEvily B., Zaheer A. (1999), Bridging ties: a source of firm heterogeneity in competitive capabilities, *Strategic Management Journal* 20 (12), 1133-1156.

Meyer M.H., Lehnerd A. P. (1997), *The Power of Product Platforms: Building Value and Cost Leadership*, Free Press, New York.

Nelson R., Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press, Cambridge, MA.

Orton J.D. , Weick K. E. (1990), Loosely coupled systems: a reconceptualization, *Academy of Management Review* 15 (2), 203-223.

Ozman M. (2009), Inter-firm networks and innovation: a survey of literature, *Economics of Innovation and New Technology* 18 (1), 39-67.

Patrucco P. P. (2008), The economics of collective knowledge and technological communication, *Journal of Technology Transfer* 33 (6), 579-599.

Patrucco P. P. (2009), Collective Knowledge production costs and the dynamics of technological systems, *Economics of Innovation and New Technology* 18 (3), 295-310.

Patrucco P. P. (2010), Changing network structure in the organization of knowledge: The innovation platform in the evidence of the automobile system in Turin, *Economics of Innovation and New Technology*, forthcoming.

Powell, W. (1990), Neither market nor hierarchy: Network forms of organization, *Research in Organizational Behaviour* 12, 295-336.

Penrose E. (1959), *The Theory of the Growth of the Firm*, Oxford University Press, Oxford.

Richardson, G. B. (1972), The organization of industry, *Economic Journal* 82, 883-896.

Robertson D., Ulrich K. (1998), Planning for product platforms, *Sloan Management Review* 39 (4), 19-31.

Schilling M. A. (2008), *Strategic Management of Technological Innovation*, McGraw-Hill, New York.

Schumpeter, J. A. (1942), *Capitalism, Socialism and Democracy*, Harper and Brothers, New York.

Simon, H. A. (1962), The architecture of complexity, *Proceedings of the American Philosophical Society* 106 (6), 467-482.

Simon, H. A. (2002), Near decomposability and the speed of evolution, *Industrial and Corporate Change* 11 (3), 587-599.

Teece, D. J. (1984), Economic analysis and strategic management, *California Management Review* 26 (3), 87-110.

Uzzi B. (1997), Social structure and competition in interfirm networks: The paradox of embeddedness, *Administrative Science Quarterly* 42 (1), 35-67.

von Hippel, E. (1994), "Sticky information" and the locus of problem solving: Implications for innovation, *Management Science* 40(4), 429-439.

Williamson O. (1975), *Market and Hierarchies: Analysis and Antitrust Implications*, Free Press, New York.