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Research Paper

The Evolution of Knowledge Organization and the Emergence of a Platform for Innovation in the Car Industry

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ABSTRACT The paper aims at explaining the changes in how economic actors and their organizations acquire and coordinate innovative and productive capabilities. Using the illustrative evidence from organizational change in the automobile industry in Piedmont over the last 50 years, the paper describes how transformations in the structure of interactions between firms are steered by changes in the pattern of specialization and differentiation in the capabilities and technological skills of economic actors. The system is characterized by the emergence of a platform for the coordination of productive and technological activities, which can be seen as a major change in the organization of innovation in the system.

KEY WORDS: Coordination, division of knowledge, networks, organizational innovation, platforms, technological knowledge

JEL Classification: O31, O32, O33

1. Introduction

A large range of contributions in the economics and management of innovation have highlighted the virtues of vertical integration versus those of modularization and outsourcing as efficient solutions to the problem of how economic agents acquire and coordinate innovative capabilities and technological knowledge.

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In particular, what can be called "the three hands debate" identified three clearly distinct modes of coordination of production and knowledge in economic history: (1) the invisible hand of the market well understood a long time ago by Adam Smith, (2) the visible hand of the corporation described by Chandler (1962, 1977, 1990) and (3) the vanishing hand of modularization, outsourcing, networks and contracts deeply analyzed by Langlois (2003, 2004) and Langlois and Garzarelli (2008) among others.

This paper argues that although both the vanishing hands of networks (Ozman, 2009; Bergenholtz and Waldstrøm, 2011) and the invisible hand of the market (Arora *et al.*, 2001) are used increasingly as modes of production and knowledge coordination, forms of hierarchy and managerial control remain crucial for sourcing technological and productive knowledge externally. In other words, both networks of innovators based on interactions and cooperation (Helper *et al.*, 2000; Lamoreaux *et al.*, 2003; Grodal and Powell, 2005) and the markets for knowledge and technology based on transactions (Chesbrough and Teece, 1996; Sanchez and Mahoney, 1996; Langlois, 2002; Sturgeon, 2002) are coordinated by quite visible hands more similar to the Chandlerian vertical hierarchy than to the spontaneous and anonymous coordination of markets.

In making its argument, the paper uses the concept of platforms—hybrid coordination modes that combine both interactions and transactions with hierarchical coordination and management of networks. Platforms are a major organizational innovation and result from a path-dependent and historical evolution in which different types of organization occur in succession. The paper illustrates this emergence through a case study of the long-term evolution of production and technological coordination in the car system in Piedmont. The case study distinguishes different historical phases characterized by specific organization forms and identifies the drivers that force the system to change type of coordination. This allows us to isolate the characteristics of the platform, and to see its advantages and disadvantages compared with the other modes of coordination.

In order to frame the case study, the paper builds upon theoretical contributions that analyze innovation as the result of the exploitation of technological complementarities and learning among a variety of actors.

The platform coordinates various resources and actors, combining the benefits of large coalitions—which include mutual learning and the acquisition of technological and productive competencies sourced externally—with those of centralized decision-making. Hierarchy is clearly evident here, since direction and authority are required in order to guarantee both the cohesion of the network and the convergence of the complex system of goals, incentives and interactions that are typical of a collective innovation processes.

The paper is structured as follows. Section 2 reviews and compares various organizational forms for the coordination of knowledge and innovation that have been discussed in the literature. Section 3 describes platforms as specific governance forms for organizing and producing technological knowledge and innovation. Section 4 describes the methodological approach used to collect and organize the empirical material about the evolution of the organization of innovation in the Turin car industry. Section 5 illustrates and articulates the emergence of a platform in the case of the Piedmontese car system. Conclusions summarize and put into perspective the main results.

2. Changing Structures for the Organization of Knowledge

The tradition of industrial economics and economics of innovation in the last century promoted the idea of the vertically integrated Fordist company, which it considered the most efficient organizational model for the production of technological innovation, thanks to the benefits from the economies of scale, scope and learning that the vertical integration of R&D activities makes possible (Penrose, 1959; Chandler, 1990).

Since the 1990s, however, various factors have emerged that have led to a rapid and radical transformation of the context in which firms compete, raising doubts about the applicability of this model in the new picture. First, the growing turbulence of markets and the intensification of global competition reduce the efficiency of management-and-control planning. Second, the greater complexity of innovative dynamics reduces firms' level of autonomy. No company is able to completely dominate all the technological and organizational competencies, nor does any have the financial resources to develop new knowledge on its own. Lastly, the scientific-technological system has expanded. This means an increase in the sources that companies must investigate to seek out new knowledge to use in their innovation operations (Davenport and Prusak, 1998; Foray, 2004; Herrigel and Zeitlin, 2004).

The vertically integrated corporation and its R&D laboratories are seeing their margins of autonomy and self-sufficiency shrink. In particular, large companies are loosing their prime position as the locus par excellence for the production of innovation. In fact, in a complex environment, characterized by continuous changes in the features of the products and production technologies, by radical uncertainty and by ever more extreme scientific and technological specialization, the individual company has difficulty in managing, purely through the capacities produced internally, all the competencies needed for the process of the generation of new knowledge.

The picture summarized above thus questions not only the model of the integrated corporation but also traditional schemes for the organization of innovation. This implies that the linear and closed model must be replaced and that firms must structure themselves so as to be able to draw advantage from the external knowledge available and integrate it effectively with knowledge produced internally (Chesbrough *et al.*, 2006).

As a consequence, consensus has grown in recent times amongst innovation scholars around the idea that, if firms are not able to develop independently a sufficient innovation capacity on their own, they can implement a variety of solutions that go from one extreme (vertical integration) to another (the market), passing through a variety of hybrid strategies, forms of strategic alliances and inter-organizational relations aimed at minimizing the costs of external coordination and maximizing the creative contribution of the individual companies. This has opened the way to the analysis of the various forms of decentralization, specialization and division of innovation and production that emerged following the crisis of the vertically integrated corporation.

Thus, a broad thread of studies on the organization of knowledge and technological innovation has directed its attention to modular systems, based on outsourcing and market transactions as the coordination mechanisms of the division of labor in innovative activity (Baldwin and Clark, 1997; Arora *et al.*, 1998; Langlois, 2002). When a system is extensive and complex, and the interdependency between the elements and subsystems becomes particularly numerous, coordination through an integrated structure is almost impossible.

Baldwin and Clark (1997) and Langlois (2002) argue that the organization of production and innovation through modular strategies is increasingly the most efficient way to organize and coordinate complex technologies and production systems.

According to this approach, firms can decide to adopt an integrated or modular organizational structure on the basis of the technologies and competencies that are the foundations for innovation: the more the knowledge and technological competencies needed for innovation are varied and interconnected, the more the adoption of a modular architecture and the recourse to formal contracts and market transactions will be efficient (Chesbrough and Teece, 1996). But the so-called loose coupling strategy has its limits. In particular, activities that demand exchanges of complex technological knowledge require the presence of integration mechanisms much more rigid, frequent and persistent than a modular organization usually guarantees (Schilling, 2008). If the activity demands an intense form of coordination, one continuous in time, a more hierarchical organizational structure may be called for to maintain closer integration between the partners involved.

Furthermore, innovation systems cannot always be broken down into discrete and distinct components as the modular structure suggests (Consoli and Patrucco, 2011). One of the main characteristics of those systems lies in the complexity of the interdependencies between their individual elements and sub-systems, where the changes in the conduct or the characteristics of one company also determine—through feedback processes deriving from the interaction between the elements—transformations in the other organizations belonging to the system. Such systems are characterized by simultaneous change and reconfiguration in different stages of production that make obsolete existing know-how, require new knowledge to be applied, and force embedded firms to acquire and develop new capabilities.

Also, empirical evidence shows that, in tackling choices linked to the organization of their own innovation activity, companies do not have to hand purely modular or purely integrated solutions. Instead, the characteristics of the two alternatives coexist, and firms are able to use a broad spectrum of inter-organizational solutions in order to combine the advantages of both options (Brusoni and Prencipe, 2001; Zirpoli and Camuffo, 2009; Consoli and Patrucco, 2011).

In this direction, a growing literature has put increasing emphasis on networks as the locus of production of innovation: networks facilitate the coordination and integration of complementary technological competencies in contexts characterized by complexity, uncertainty and the dispersion of competencies among heterogeneous sources, avoiding the costs and inefficiencies of full integration (Powell, 1990; Uzzi, 1997; Burt, 2000; Helper *et al.*, 2000; Kogut, 2000; Love and Roper, 2009; Ozman, 2009). Innovation studies have progressively asserted the idea that inter-organizational links and hybrid forms of organization are more effective solutions for the management of innovation, in that collaboration aids the access to a wide range of complementary technological competencies, representing an opportunity to recombine existing resources and competencies developed by individual companies. Combining the flexibility typical of market-based solutions with the visible hand of the organization, inter-firm links reduce the access costs to varied and scattered sources of knowledge, which in turn forms the basis for the creation of new knowledge and thus of the innovation process.

Much analysis of the effectiveness of networks as models of governance of innovation has focused on the nature of the relations and roles played by the various actors within the networks. The structure of the network influences the learning curves of firms. Analyses have concentrated on the respective advantages of the various structures of relations that occur within a network, and in particular on two contrasting configurations: on the one hand, networks characterized by strong and abundant ties, and on the other hand, networks characterized by structural holes and weak ties.

According to Coleman (1990), for instance, networks characterized by strong ties would generally be associated with an intense exchange of information, effective mechanisms of transfer of tacit knowledge and reciprocal trust between partners. For these reasons, these links would be more efficient for the exchange and communication of complex knowledge, in that they would allow the establishment of more efficient cooperative attitudes, thanks to the repeated exchanges and a balanced distribution of power within the network. In contrast, according to some other authors (Granovetter, 1973; Burt, 1992), networks characterized by weak connections and by structural holes—which play a role as broker, directing and coordinating the flows of knowledge between companies or groups of companies not directly linked to each other—would represent more efficient solutions because of the advantages of a partially hierarchical organizational form. Here is where platforms come into the picture.

The platform is a new form of governance of knowledge that emerges as an effect of the dynamics of collective systems—because of the interactions between interdependent and learning actors (Patrucco, 2012). In particular, platforms can be defined as hierarchical networks, as networks in which the interactions do not emerge and evolve spontaneously, but in which key players (like platform leaders and system integrators) guide the behavior of the other actors, selecting the members of the platform and directing the evolution of the system as a whole. A second distinctive element of these organizational forms is the active search for knowledge complementarity and the exploitation of variety (contrasted to mere agglomeration) between different activities; in other words, platforms are structured and designed with a view to precise and pre-determined innovation objectives (in contrast to spontaneous phenomena such as industrial districts) (Gawer and Cusumano, 2002; Prencipe *et al.*, 2003; Consoli and Patrucco, 2008).

In this sense, the platform represents a major organizational innovation, different from the integrated company, the market and networks themselves with respect to both type of coordination and the characteristics of the knowledge coordinated. Table 1 summarizes these differences.

Table 1. Knowledge and coordination in different types of organization

	Coordination	
Knowledge	Spontaneous	Directed
Complete	Market	Vertical integrated firm
Fragmented	Networks Industrial districts	Platforms Modularized networks

3. Platforms and Innovation: The Building Blocks

Wheelwright and Clark (1992) first talked of platform products whose core design seeks to appeal a large customer base while its openness to marginal modifications attempts to captivate peripheral users with more specific needs. A few years later, Kim and Kogut (1996) talked about platform technologies as models for the coordination of complementary components such as computers. Rochet and Tirole (2003) first went beyond the physical features of artifacts, thinking of platforms as a design concept. In general, management scholars connect platforms to the challenges and the strategic implications associated with the emergence of open systems of production, exchange and govern competencies (Gerstein, 1992; Ciborra, 1996; Garud and Kumaraswamy, 1996; Ethiraj and Levinthal, 2004; Jacobides and Billinger, 2006).

Gawer and Cusumano (2002) and Gawer (2009) successfully elaborate the concept of "technology platforms" in order to account for information and communication technology (ICT)-based innovations such as virtual networks and modular structures. They emphasize associated infrastructures, interfaces and standards. From this viewpoint, technology platforms facilitate interoperability between different firms and technologies in the context of, for instance, high-tech industries.

In the perspective of innovation studies, Consoli and Patrucco (2008, 2011) and Patrucco (2012) stress instead the implications of platforms for the coordination of technological knowledge, articulating the notion of "innovation platforms" as hybrid coordination modes that combine both interactions and transactions with hierarchical coordination within networks. Innovation platforms are organizational innovations for coordinating specialized and complementary actors.

Despite their differences, common to both technology and innovation platforms is the notion of directed and coordinated organization as opposed to spontaneous and anonymous organization typical of market processes. The concept of innovation platform emphasizes, first, the coexistence of both market transactions and collaborative interactions and, second, that they produce an outcome—an innovation—that is the result of collective learning and alignment of investments.

In platform organizations, a variety of agents participate in the production and supply of products and services; each unit exists independently according to own goals and capacity, but at the same time responds to a collective goal through shared communication rules. In this regard, a central component of the rationale for platforms is maximizing the variety of contributions stemming from a variegated knowledge base while maintaining coherence through a minimum level of hierarchy deployed by key firms as platform leaders. As will be discussed further, platforms are purposely open to entry of new actors and, thereby, of new competences: the extent of contribution by each additional unit depends endogenously on the relative value of internal competences measured against the collective goal.

Along these lines, recent contributions by Baumol (2002) and Von Hippel (2005), for instance, stress the incentives of knowledge sharing for firms within a platform. Combining internal investments and external learning leads to greater efficiency than if knowledge creation relies exclusively on either internal creation (i.e. vertical integration of R&D) or external acquisition (i.e. outsourcing of R&D and design).

From a static viewpoint, platforms connect and integrate activities and capabilities of relevant agents within an industry, thus supporting specialization and favoring the accumulation of specific knowledge. From a dynamic viewpoint, platforms stimulate changes in both the structure of the network and the mechanisms for the governance of technological knowledge.

Let us now draw attention to some of the dynamic properties that characterize the production of innovation by means of platforms, namely hierarchical causation, coordinated variety and selective openness. The juxtaposition of these three helps us see the texture of connections that make up platforms for innovation.[1]

3.1 Hierarchical Causation

What stimulates the emergence of collective structures such as platforms devoted to the production and organization of technological knowledge and innovation? Let us, in answering this question, adopt a functional approach and argue that platforms are purposive responses to specific problems that no individual firm can solve in isolation. The general phenomenon is very common across most modern industries. Each firm possesses a knowledge base, which is usually accumulated by blending information inputs, know-how and capabilities while searching for and developing innovative solutions (Nelson and Winter, 1982; Teece, 1993; Cohen and Levinthal, 1989). Industries with a complex knowledge base accelerate the obsolescence of firm-specific knowledge assets, thus forcing them to either invest in internal competencies or sourcing knowledge externally. Each of these solutions carries its own risk. On the one hand, highly specialized knowledge is sticky and may differ considerably from the skills already possessed by a firm (Pisano, 1996). On the other hand, significant communication costs stand in the way of knowledge spillovers among firms. Such costs are affected by specific characteristics of the competitive environment in which firms operate (Patrucco, 2008). Either way, a firm under pressure needs to adopt effective governance mechanisms to overcome the barriers to creative reaction.

As we will see in detail in Section 5, in the auto industry in Piedmont, the original equipment manufacturer (OEM) risked failure because of both strong competitive pressure and faulty organizational strategy. As a reaction, the OEM adopted a new governance mechanism to reconfigure the organization of internal as well as external competencies. In this new system, the OEM retained hierarchical control over the net of suppliers and partners.

As Burt (2008) remarks, learning is not an optional attribute of collective structures: in dynamic environments where the scope of collaboration and the operative rules are liable to change, inclusion depends on the ability to remain relevant. That is to say, participation is contingent on learning and adaptation. Platform leaders retain control over “entry and exit” in the network of partners.

In this respect, the notion of platform sees innovation as happening efficiently and successfully when partnerships form because of a convergence of incentives and structured complementarity of the competencies of a variety of heterogeneous actors, which increases the cohesion of the group and organizes the intrinsic complexity of the system around

[1] What follows is based on an elaboration of Consoli and Patrucco (2011). I thank my co-author Davide Consoli for allowing the use of our material in the present paper.

common purposes and shared goals. Efficient platforms emerge, in fact, when the various incentives and the complementary capacities of a multitude of heterogeneous actors involved in a network are organized and aligned so as to ensure the cohesion of the network and the coordination of the division of technological knowledge and labor in the innovation process.

3.2 Coordinated Variety

Innovation scholars suggest that the growth of knowledge is rarely, if ever, the outcome of isolated action but rather of collective learning and cumulative interactions. On the one hand, the development of tacit knowledge moulds individuals' responses and is a source for new ideas and solutions, and on the other hand, codified and practical knowledge are both crucial to facilitate exchange and interaction among individuals. Contrary to the common view that these dimensions are mutually exclusive, we stress their complementary aspects: new knowledge grows as a result of coordination across individual experiences and the development of shared understanding. At the same time, variety and heterogeneity are not sufficient to replenish the knowledge base, and individual specialization is most effective when coordinated through formal and informal mechanisms (Gilson *et al.*, 2009). The collective character of knowledge, in turn, elucidates the importance of establishing sound governance mechanisms (Antonelli, 2006). Previous literature sidestepped these points by assuming implicitly that agents learn and adapt swiftly to collective environments.

Instead, innovation and the creation of new technological competencies are more and more frequently seen as a collective and distributed phenomenon, based on a high degree of complementarity between internal investments in R&D and the learning of technological resources acquired externally from other companies (e.g., customers and suppliers, competitors) and from research bodies (e.g., universities, public laboratories and technology transfer centers) (Allen, 1983; Cowan and Jonard, 2003).

In line with the pioneering contribution of Nelson and Winter (1982), in which economic change is the product of the action of actors who possess idiosyncratic and highly specialized abilities, technological competencies are therefore characterized by a rather limited degree of interchangeability and substitutability—but by high levels of complementarity (Patrucco, 2008): screening and learning are necessary for accessing knowledge sourced externally and for exploiting externalities efficiently.

Some authors (Cohen and Levinthal, 1989) speak of the "two faces" of R&D and of the importance of investing in internal R&D so as also to be able to use knowledge arriving from outside. This implies, for instance, that internal R&D activities assume new functions: their role is no longer limited to the production of new technological knowledge but includes the identification and understanding of the external knowledge available; the selection and integration of external knowledge with internal knowledge in order to produce more complex combinations and the generation of further profit through the sale of in-house research work to others who wish to use it in their own innovation process (Cohen and Levinthal, 1990).

A clear trade-off is involved in the pursuit of specialization when a large knowledge base is available (Kogut, 2000). Such a trade-off defines the scope, the boundaries and the forms of inter-organizational relations within a platform. On the one hand, specialization favors efficient communication within a narrow set of partners but limits both the scope for coordination and accessibility to innovative opportunities. On the other hand, the coordination of a bundle of inter-firms and inter-organizations linkages opens up new opportunities but lowers the scope for specialization and the benefits of communication (see Kogut and Zander, 1992). Platforms reduce the inefficiencies associated with these trade-offs.

3.3 Selective Openness

To be viable, infrastructures such as platforms require on the one hand a degree of stability that confers coherence to shared goal and on the other hand room for further novelty. From this it follows that a necessary condition for the emergence of novelty is that a system maintains a degree of openness to be able to adapt to modified circumstances.

The key point is that major technical changes generate new opportunities for learning but also lead to skill shortages. For instance, empirical work such as that by Brynjolfsson and Hitt (2000) demonstrates that the large-scale diffusion of ICTs, often the backbone of platforms, stimulates the emergence of new tasks and competencies. In turn, the degree of openness of the platform determines where new knowledge comes from and the costs for this knowledge to be absorbed, integrated and used by different members of the network.

As anticipated by Richardson (1972) and reiterated by many others, when coordination between closely complementary activities and competencies is essential for the success of innovation, firms rely upon a variety of inter-organizational arrangements—such as joint ventures, equity agreement, R&D partnerships, coalitions and consortia—to blend market- and contract-based and integral solutions, strong and weak relations, in order to acquire and coordinate the necessary productive and innovative knowledge. Complex and articulated governance forms emerge when the task is the coordination of knowledge sourced both internally and externally.

Concepts such as architectural knowledge (Henderson and Clark, 1990) or architectural capability (Jacobides, 2006), or the notion of system integrators (Prencipe *et al.*, 2003), have been introduced recently to describe precisely that decisive capacity, possessed by the platform leaders, to coordinate and manage the work of complex organizations, and more precisely to combine elements typical of the integrated models (such as authority and control) with characteristics typical of networked structures (such as a sufficient degree of openness) in order to select the significant competencies and knowledge to include in the network.

In a context of distributed capabilities and knowledge often sourced externally, the challenge for individual firms is to enlarge the range of external capabilities that can be accessed and integrated with internal ones, while guaranteeing efficiency and cohesion in access and integration of external knowledge as well as the distinctiveness of capabilities.

In the car industry, for instance, this seems precisely to be the case of the design and development of electric vehicles (EVs), which involved large partnerships, often embedding public actors and newcomers. In many cases, significant technological and market competencies came from outside the car industry strictly considered (Aggeri *et al.*, 2009; Beaume and Midler, 2009). The introduction of EVs is arguably a collective innovation wherein different actors such as traditional OEMs, automobile batteries producers, utilities and system integrators contribute with complementary resources as well as technologies, and converge towards common goals and incentives. At the same time, some elements of managerial authority still crucial in that direction are required in order to guarantee both cohesion within the network and the convergence of the complex system of goals, incentives and interactions that characterize such an articulated innovation process (Enrietti and Patrucco, 2011). The integration, coordination and direction of the different strategies and goals of various organizations that take part in the platform should be a central issue of the platform management.

Table 2 compares the main coordination forms and summarizes the main characteristics, costs and benefits of the market, the vertical corporation, the network and the platform.

4. Methodological Approach

The methodological approach adopted can be defined as "appreciative theorizing" (Nelson, 1994, 1998; Malerba *et al.*, 1999; Feldman, 2001). Appreciative theorizing is appropriate in the analysis of the organization of innovation and knowledge because of the high level of social embeddedness of the collective process of knowledge generation and distribution, where interaction and evolutionary processes cannot be fully captured by formal models and may often be expressed only in qualitative terms. As Nelson put it:

> appreciative theorizing tends to be close to empirical work and provides both interpretation and guidance for further exploration. Mostly is expressed verbally and is the analyst's articulation of what he or she thinks really is going on. However, appreciative theory is very much an abstract body of reasoning. Certain variables and relationships are treated as important, and others are ignored. There generally is explicit causal argument. On the other hand, appreciative theorizing tends to stay quite close to the empirical substance. (1994: 500)

In this spirit, the paper proceeds with an analytical interpretation of the evolution of the organizational form that has coordinated innovation and technological knowledge in the automobile industry in Piedmont over the last 50 years.

A set of interviews has been conducted with corporate managers, as well as with local policy makers, expert analysts and members of collective bodies knowledgeable about the process of organizational change experimented in the local car industry. This took the form of reiterated focused groups of open and vis-à-vis interviews with 16 interviewees. Discussion centered around the following broad issues: the origins of the system; the industrial dynamics that characterized it over the last 50 years; the characteristics of innovation process over the last 50 years and the forms of its organization and coordination. Interviews were guided in order to gather information about (a) which firms command technological competencies key to innovation along the evolution of the car system; (b) what where the forces that drove the system from one stage to another; (c) what are the structural characteristics of the different "architecture" in the different stages of its evolution, with a special attention to and (d) what are the knowledge interactions and flows that support the innovation process.

Since issues such as interactive behaviors, knowledge sharing and cooperation are extremely complex, open and face-to-face interviews allow capturing the very qualitative nature of such interdependences. Moreover, the organization of very close interview groups of selected members of the local "car community" allows the gathering of information from collective, interactive and in-depth discussion, at the same time leaving room for unexpected issues emerging from the discussion, and in turn also strongly motivating the commitment of the participants in the research work.

Table 2. Characteristics, costs and benefits of the different coordination forms

	Coordination form			
Features	The integrated firm	The market	The horizontal network	The hierarchical network
Coordination	Managerial control	Price mechanism	• Spontaneous interactions (districts) • Market transactions (modularized networks)	Directed
Inclusion	Limited	Free (no barriers to entry)	Open and diffused	Selective variety
Design costs	High	Null because of emerging order	Low because of spontaneous coordination	High
Networking costs	Low	Null because of perfect information	High due to redundant connections	Limited because of platform leader gatekeeping
Production costs	High	Low because of the division of labor	Low because of the division of labor	Conditional to the mix of internal production and external sourcing
Transaction costs	Low	High	• Low (districts) • High (modularized networks)	Conditional to the mix of internal production and external sourcing
Knowledge	Perfect	Perfect	Fragmented (both in district and modular networks)	Fragmented
Product design strategy	Top-down and ex-ante	Bottom-up and ex-post	• Bottom-up and ex-post (district-like networks) • Top-down and ex-ante (modularized networks)	Co-design
Flexibility of production	Low	High	High	Limited
Economies of specialization	Limited	High because of the division of labor	High because of the division of labor	High because of competences variety
Economies of scale and scope	High	Null	Internal to the network	Internal to the platform
Learning economies	Bounded to firm competencies	Competencies sourced externally	• Collective learning (district) • Competencies sourced externally through transactions (modularized networks)	Search for complementarity and collective learning

(*Continued*)

Table 2. (*Continued*)

	Coordination form			
Features	The integrated firm	The market	The horizontal network	The hierarchical network
Circulation of knowledge	Limited to the firm boundaries	Free	• Open and diffused (district) • Conditional to IPRs (modularized network)	Selective
Innovation process	Internal R&D	Creative destruction	• Knowledge externalities (district) • Private R&D (modularized network)	Collective (integration of internal R&D and external sourcing)

5. Platform and the Coordination of Knowledge in the Evidence of the Car System in Piedmont

The technological and knowledge base in car production requires the understanding of different and complementary technological fields from its very beginning. This complexity has lately been increasing from both the static and dynamic viewpoint. Car production requires the full understanding of the complementarities within a wide range of different technologies and materials, and therefore the command of a very diversified set of knowledge modules in engineering, electronics, chemistry, plastics technology, robotics, informatics and telecommunications. Each of these modules cannot, however, be fully commanded internally by the firm. Knowledge requires the integration and recombination of external and internal knowledge via the supply and demand of products, components and process technologies.

Historically, the integration, recombination and in turn the coordination of such a growing number of components, technologies and modules of knowledge have been achieved through an increasing division of labor, specialization and outsourcing. These are the results of the intertwining effects of market saturation, product differentiation, demand uncertainty and financial pressure that bring about increasing needs of operational efficiency and therefore organizational and technological change. From the organizational viewpoint, car production is therefore clearly characterized by strong specialization, strong division of labor and therefore important coordination costs.

Such increasing specialization and fragmentation lead OEMs (i.e. car-makers) along a variety of paths to outsource production processes and activities. Know-how and capabilities are distributed quite differently across both OEMs and suppliers. Product architecture in the car industry can differ substantially from model to model. Interchangeable modules, components and activities across models, OEMs and suppliers are limited due to significant variations in know-how and competencies. Different suppliers are characterized by different capabilities: providing even the same activity or component to different clients implies different competencies for the same supplier. Selection among suppliers and the emergence of preferential relationships are important in this context. Suppliers' activities and capabilities are not fully interchangeable and modular, nor fully reversible. Knowledge modules are not completely interchangeable because of the specific, idiosyncratic and non-disposable part of know-how. This in turn implies important costs for OEMs. Important switching costs are associated with shifting from one supplier to another and with changes in the technology modules and in the design of the system and the architecture of coordination. Long-term interactions and quasi-integration between OEMs and suppliers emerge in turn as an effect of such costs (Sako, 2003).

Interaction between actors is crucial for such coordination, and successful product innovation (i.e., the introduction of a new car) implies the ability to coordinate in the more appropriate way the wide networks of specialized suppliers and partners. In other words, product innovation is directly related to the ability to introduce and manage changes in both the organization and production processes.

In this regard, the Piedmontese automotive sector underwent and is currently undergoing a phase of strong structural and organizational change because of the difficulties experienced especially in the 1990s by the main OEM. As the mingled result of increasing complexity in the knowledge base and the crisis of the OEM, car production in the

Piedmontese system has been characterized by progressive vertical disintegration and strong externalization of more and more complex and specialized components and processes. This results in the stronger and stronger need for coordination of the division of labor and communication between specialized producers and users. Such a need for coordination mechanisms is paralleled by the declining role of the OEM as the traditional "hub" of the network of small and large suppliers and R&D institutions. The lack of centralized coordination was one of the main problems that arose from the crisis of the OEM, which was in no way a crisis of the Piedmontese automotive system as a whole. The Piedmontese car industry is in fact today a sophisticated multi-firm productive system characterized by a complex network of highly specialized suppliers for the international market, design firms, machine tool firms, research and training organizations and university programs (Enrietti and Bianchi, 2003).

The evolution of the organization and coordination of innovation in car production paralleled the disappearing of technological capabilities internal to the OEM.[2] This evolution had four phases (Table 3): (1) coordination through vertical integration, (2) coordination through a centralized network of local suppliers, (3) coordination through a decomposed network and (4) coordination through platform (Table 1). The OEM moved from a vertically integrated production structure to outsourcing the production of components to local small suppliers; to the decomposition of the production and innovation processes, together with the outsourcing of strategic and high-valued activities such as design and R&D; to the adoption a modular architecture and finally to full co-innovation and co-design. The changes in the organization of innovation can be described as follow:

(1) Coordination through vertical integration was typical in the 1960s and 1970s. Coordination of innovative and productive activities took place through the "Fordist" firm and was based upon internal R&D, internal capabilities in the design of cars models and internal capabilities in technology design. Innovation took place exclusively within the OEM itself.
(2) Coordination through centralized networks of local suppliers progressively takes place during the 1980s, as a reaction to uncertainty in both demand characteristics and the supply strategies appropriate to meet the changes in consumers' needs and requirements. The vertically integrated carmaker is induced to change its coordinating structure. Here, the OEM outsources manufacturing activities and the production of components to local small suppliers, creating a local and closed productive network of suppliers still dependent on and coordinated centrally by the OEM. R&D and design are handled ex-ante by the OEM and the results transmitted in a top-down fashion to suppliers.
(3) Coordination through decomposed network arose more and more importantly in the 1990s.[3] Suppliers became able to benefit from economies of specialization and learning, accumulating competencies that helped these firms emerge as first-tier suppliers (FTSs). On the one hand, FTSs were also able to integrate themselves into international productive networks and became international suppliers to carmakers.

[2] A key source on the history of the Turin car industry and FIAT has been Volpato (2004, 2008).
[3] On this phase, see Becker and Zirpoli (2009) and Zirpoli and Becker (2011).

Table 3. Organizational changes in the coordination of production and innovation in the Piedmontese automotive system

Phase	Coordination structure	Organization characteristics	Innovation process	Drivers to change
Phase I: 1970s	The firm	• Vertical integration of production • Internal accumulation of R&D • Internal accumulation of capabilities in the design of car models • Internal accumulation of capabilities in technology design	• Innovation in isolation	• Diseconomies of scale
Phase II: 1980s	The centralized network	• Outsourcing of small components and spare parts • Central coordination of suppliers by the OEM • Exclusive supply from small suppliers to the OEM	• Ex-ante and top-down design of car models, components and technology • Innovation undertaken internally by the OEM	• Diseconomies of scope (OEM) • Decreasing returns to R&D (OEM) • Financial constraints (OEM) • Economies of specialization and learning (suppliers)
Phase III: 1990s	The decomposed organization	• Suppliers benefit from economies of specialization and learning • FTSs emerge as innovators at the local and international levels • Outsourcing of components • Outsourcing of design in both components and modules • Modular product and system architecture design	• Outsourcing of R&D and design • Bottom-up (FTSs driven) innovative process	• Losing control (OEM) • High transaction costs • High levels of hold-up problem

(*Continued*)

Table 3. (*Continued*)

Phase	Coordination structure	Organization characteristics	Innovation process	Drivers to change
Phase IV: 2001—ongoing	The platform	• In-sourcing of innovative and value-adding activities • Acquisition of external resources built in phase III • Vertical cooperation between OEM and FTSs • Horizontal cooperation between OEMs and between FTSs • Internal to the OEM product and system architecture design	• Integration of top-down (OEM) and bottom-up (FTSs) innovative process • Co-design • Co-innovation	

Source: Systematically updated and changed from Consoli and Patrucco (2008).

On the other hand, they were able to move from the mere provision and supply of simple components to the provision of product design services. Now the OEM choose to outsource those strategic activities such as design, and to transfer to suppliers not only activities but also autonomy and key decision processes in terms of the design features. This was clearly possible only in that suppliers accumulated specialized competencies with regard to product design, and more generally with regard to innovative. Innovation took place in a bottom-up manner, driven by the competencies of FTSs, while progressively robbing the OEM of both its innovative competencies and its coordinating role in the network. One can argue that new Burt-type structural holes emerge (i.e., FTSs) because of the coupled effects of positive economies of learning and specialization by FTSs and of negative effects of the declining organizational and innovative capabilities of the OEMs.

(4) Finally, coordination through platforms became possible only when in 2001 the OEM decided to start bringing back R&D and design in house, reacting to the loss of innovative capabilities experienced in the previous phase, and yet being still able to rely on the complementary R&D and design competencies developed by FTSs. The OEM can now combine its internal know-how with that of the FTSs, thus being able to take advantage from synergies and technological partnerships through appropriate collaborative strategies. Moreover, the OEM is now again able to coordinate the innovation process because of new internal R&D and design activities. In parallel, coordination strategies support the introduction of a variety of “de-layered” organizational relations, which benefit from a wider pool of resources and knowledge, where technological cooperation can take place vertically (i.e., within OEM’s supply chain), horizontally (i.e., with other OEMs, also through international alliances) and diagonally (i.e., through different supply chains by means of FTSs that cooperate with different OEMs). Innovation is the result of the integration of top-down and bottom-up innovative processes and takes place in a truly cooperative way, through the bidirectional exchange and communication of technical information, innovative capabilities and the results of R&D and design activities developed both by the OEM and the FTSs. Here, transformation also includes changes in the number and quality of actors, integrating in the platform new suppliers and partners according to new emerging technological needs, and excluding old ones. It seems plausible that a Coleman-type of relationships emerged in this context, in which redundant connections as well as technological competencies bring forth a collective model of innovation based upon the exploitation of the complementarities among the skills of the various players.

So, there are four models of the organization of innovation (Figure 1). The network transforms from centralized, limited in the number of connections and characterized by one-way relations (in phase II—The centralized network), to vertical and yet limited (to OEMs and FTSs) cooperation (phase III—The decomposed network), to distributed, horizontal and vertical communication strategies (in phase IV—The platform).

As a matter of fact, important changes involved not only the choice between make and buy, between internal production and external provision, but also the way in which the OEM coordinates and manages external supply. A straightforward example is the change in the management of the suppliers’ network and their activities. Prior to the adoption of the

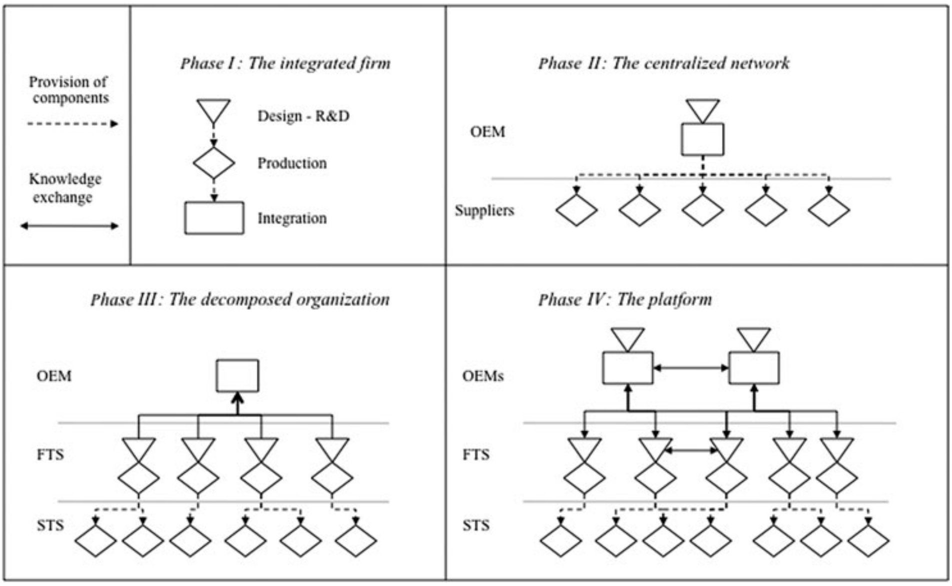

Figure 1. The evolution of the coordination of innovation activity in the Piedmontese automotive system

platform model, the definition of new cars and component characteristics and the process of their acquisition from suppliers was defined ex-ante and dominated by the design centrally specified by the OEM: given ex-ante characteristics of components, the OEM set prices and identified the appropriate suppliers. With the adoption of the platform organization, and with progressive decentralization of activities partly engendered by the accumulation of competencies by suppliers, the process reverts. Now the OEM defines the general design and characteristics of a new car model and communicates such information to the network of suppliers. Based on its specific technological knowledge and price/quality requirements, each supplier elaborates a project for the production of the given component or system. The competition among suppliers makes the more appropriate projects emerge and allows the OEM to select the more appropriate suppliers. Only after such competition and selection processes does the negotiation between the OEM and the selected suppliers define precisely the characteristics and the prices of the component or system.

This transformation leads to the emergence of a innovation platform (Figure 2) in which medium-sized suppliers acquire new centrality in both the organization of and innovation in car production in Piedmont, thanks to their ability to accumulate and create new internal technological knowledge. The performance of the system now is very much dependent upon the performance of these FTSs, together with the restored innovation and coordination capabilities of the OEM, especially in terms of higher efficiency in production, of better quality of components and modules, and of innovative capabilities brought into the process.

From the viewpoint of external governance and the coordination of the network of suppliers, the process of progressive transfer of upstream strategic activities and autonomy from the OEM to suppliers (Whitford and Enrietti, 2005) put in place in the 1990s involved not

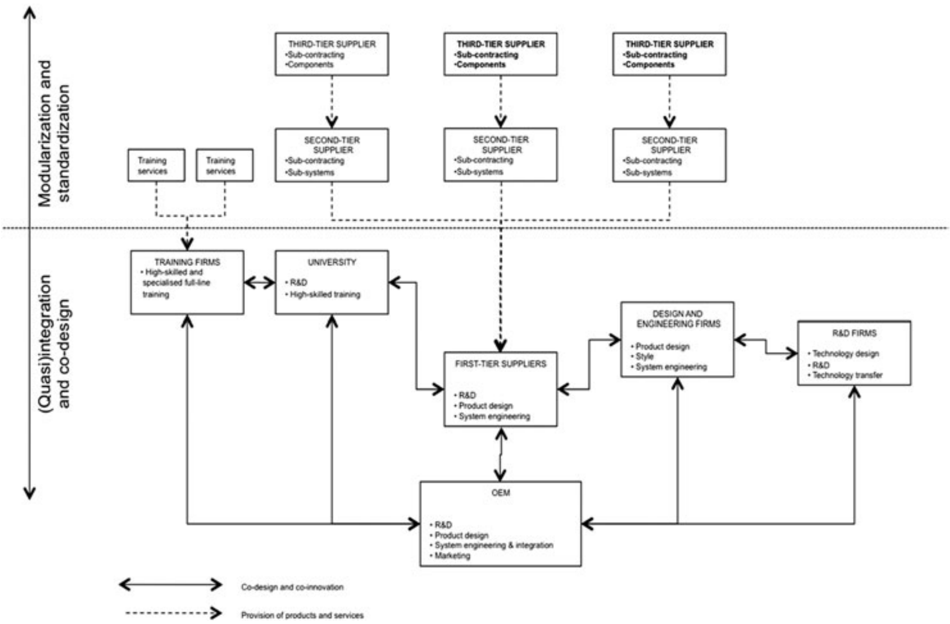

Figure 2. The platform in the Piedmontese automotive system

only FTSs but also, nowadays, second-tier suppliers. It can be seen as an effective mechanism of the dynamic coordination of the division of innovative labor.

Although the decision to adopt the platform was decided centrally by the OEM, the new mode of coordination implies the integration of top-down resources and capabilities provided by the OEM [i.e. the general and macro "template" of a new car, to use the terminology introduced by Becker and Zirpoli (2007)][4] with the bottom-up innovative activities provided by specialized suppliers (i.e. the actual implementation of modules and components with new features and performances). This integration is especially relevant in terms of the dynamic coordination of the production of new car models. A new car model is now an emergent property of the cooperative efforts of the OEM and suppliers along the entire production chain, aiming at the development and exploitation of complementarities in different activities, technologies and spaces of competencies. The introduction of a new car model is now possible only in that the OEM and the specialized suppliers co-design the features of the variety of components and modules that need to be integrated into the new final product. The effective coordination of this innovative process, and the successful

[4] Becker and Zirpoli (2007) articulate an in-depth analysis of the corporate strategy implemented by the OEM in the last phase described by this paper. In particular, Becker and Zirpoli focus on and develop the implications for the strategic management of product innovation. Their emphasis is on the changes introduced in the product architecture as a consequence of organizational transformation at the supply chain level. By contrast, this paper is focusing on the transformation of the architecture of the innovation network in which the OEM is embedded and their implication for the organization of technological capabilities.

introduction of new cars, is now possible only because of the adoption of a distributed platform that supports the interaction between the different organizations.

In sum, in the case of the Piedmontese automobile cluster, the emergence of a new organizational form for the coordination of innovation is the result of the matching between bottom-up processes of differentiation in the specialized activities of supplier firms, and top-down implementation of new organizational principles and a new management of the supplier's network. The latter is developed by the OEM as a reaction to two main factors: (1) the differentiation process put in place by FTSs in particular—their accumulation and acquisition of new technological competencies in R&D and design, that are value-added and knowledge-intensive activities, in contrast to their previous focus on mere supply of components; and (2) the diminishing innovative competencies of the OEM, as a result of the adoption of strong outsourcing strategies in the 1980s. The new structure of relations we finally observe is the emergent outcome of the interaction between micro-behaviors and macro-elements of the system, and produced renewed business model and recovered innovative competencies at the level of the entire system (*The Economist*, 2008).

6. Conclusions

This paper deals with an issue of economics of organization, and more precisely with the question of how economic agents and their organizations acquire and coordinate innovative capabilities and new knowledge.

Following the seminal contribution of Pavitt (1998) and a rich stream of empirical studies that has enriched the understanding of the implications of the division of labor for the organization of innovation (Brusoni and Prencipe, 2001; Jacobides, 2005; Brusoni *et al.*, 2011), the paper presents the illustrative case of the evolution of the organization of innovative and technological competencies in the car production system in Piedmont over the last 50 years.

The emergence of a platform organization is described in order to explain the properties and effects of the introduction of transformations in the coordination structure of the innovation process, and more precisely in the way in which firms acquire and coordinate innovative capabilities and new knowledge.

In this respect, the paper stresses two aspects well known in innovation studies: (1) the fragmentation and dispersion of technological capabilities, which is directly derived from the distinctiveness and specificity of the knowledge each organization commands (Nelson and Winter, 1982; Patel and Pavitt, 1997); (2) the interdependence and incomplete decomposability of organizations and socioeconomic systems at large (Padgett and Powell, 2012).

The paper discusses platforms as governance forms historically alternative to the market and the vertical corporation, able to overcome the trade-off between the fragmentation of knowledge and the interdependence of innovators, and appropriate for coordination of distributed innovation processes characterized by high degree of complementarity, division of labor and specialization of activities and competencies.

The emergence of a platform committed to the organization of innovation as a path-dependent process is clear through the changes that occurred in the organization of technological knowledge and innovation in the Piedmontese automobile system. The system has been characterized by important transformations in its structure as the effect of three intertwining elements: (1) the progressive vanishing of the OEM's organizing and innovative capabilities in the 1990s; (2) the increased importance of FTSs in terms of both coordinators and innovators in the networks because of the advantages derived from economies of scale and specialization and (3) the reaccumulation of internal R&D and innovative skill within the OEM from 2001. The platform derives as the emergent result of complex dynamics that are based upon the interaction of these three processes. In particular, the organizational form emerging in the Piedmontese automobile system in the last decade combines elements of hierarchical coordination with elements of openness and decentralization, sees innovation as the result of processes and activities conducted collectively and sees new players (i.e., FTSs) taking position at the center of the innovation process both as suppliers and as integrators. The acquired centrality of those players entails not only the introduction of new competencies and technologies, but also the redefinition of roles and power relations within the sector. The analysis of the entire system of complementarities becomes fundamental at this point to understand how the introduction of new organizational form changes the architecture of the relations between OEMs and suppliers at various levels, and consequently the structure of the relations of collaboration between different actors, which we have seen is decisive for the success of the introduction of new technology.

Such a systemic reconfiguration is driven, in a truly Marshallian fashion (Bloch and Metcalfe, 2011), by the differentiation of the activities of actors and the changes in the organization that coordinate the division of labor among those actors. In other words, two kinds of differentiation are at work here: (1) differentiation in the functional and technological specialization of firms and (2) differentiation in the architecture of the system. In particular, changes in the functional specialization of firms makes individual actors nonindependent and not even nearly independent of one another. Differentiation changes the structure of the system since new characteristics and capabilities of the firms are introduced. These transform the relationships between actors, in turn transforming the structure of the system, i.e., the structure of interactions between actors. This in turn affects the role and position of single firms in the network, with firms unable to adapt and react to the new technological requirements becoming peripheral and possibly exiting the network, while firms able to redirect resources and create new capabilities acquire new centrality and leadership.

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