Organizational innovations, ICTs and knowledge governance: the case of platforms

ORGANIZATIONAL INNOVATIONS, ICTs AND KNOWLEDGE GOVERNANCE: THE CASE OF PLATFORMS[1]

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1. INTRODUCTION

Platforms are a major organizational innovation that builds upon the new opportunities provided by ICTs to improve efficiency in the generation and exploitation of technological knowledge. Platforms are organizational devices that support the integration of complementary knowledge in the generation of new technological knowledge and increase its scope of exploitation and appropriation. As such platforms can be considered an organizational innovation induced and made possible by a technological innovation.

More specifically platforms can be regarded as an innovative organizational mechanism that enhances the capability of its members to command the integration of knowledge externalities in the recombinant generation of technological knowledge and to increase their capabilities to appropriate it with a better exploitation. As it is well known technological knowledge as an economic good has several limits ranging from partial appropriability and divisibility, to non-excludability, non-exhaustibility and intrinsic tacitness. The generation of technological knowledge is a recombinant process where knowledge is at the same time the output of a dedicated process and an indispensable input. The access to existing knowledge is crucial to generate effectively new knowledge as much its appropriation is necessary to provide adequate incentives and to guide a correct allocation of resources for its generation. Because of the intrinsic complexity of this trade-off, perfect markets and pure hierarchies fail in the allocation and organization of resources to its generation and use. Sophisticated knowledge governance mechanisms are necessary to organize its generation and exploitation (Arrow, 1969). Platforms are major organizational innovation that makes it possible to improve the responsible participation and the dynamic identification of competent players in a collective and yet selective process of knowledge generation and exploitation that is based

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upon incentive and reward mechanisms that make it –better-possible the division of labor among firms that command complementary competences and the internalization of knowledge externalities. Information and communication technologies (ICTs) provide the indispensable background support with the quantum jump in the capability to search, retrieve, store, process, share, command and monitor information feeding the recombinant generation of knowledge (Van Schewick, 2010, Brynjolfsson, 2011).

Platforms are a key element of the emerging knowledge economy because they make it possible to 'industrialize' the generation of knowledge and to reduce the effects of the knowledge trade-offs that limit the working of both the markets for knowledge and hierarchies, implementing the organization of the necessary division of scientific labour, the identification of the incentives to specialization and improving the opportunities for the exchange of different knowledge items (Ostrom and Hess, 2006; Ostrom, 2010; Antonelli, 2014).

The notion of a "knowledge economy"[2] precisely emerged gradually in the '90s of the XX century, to appreciate and describe some deep changes occurring in the structure and dynamics of economic systems, as well as in the competitive drivers firms rely upon in order to increase their economic gains and market power. The term "knowledge economy" was meant to stress the shift in importance from traditional physical inputs in production processes, such as capital and labour, to immaterial inputs such as competences, skills and knowledge (OECD, 1996).

As a matter of fact, since the '90s of the XX century, an array of factors have emerged that led to a rapid and radical transformation of the environment in which firms compete, raising questions about the applicability of the traditional capitalistic 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).

In this context, new information and communication technologies (ICTs) played a major role since they contributed to change the innovation landscape being centrifugal forces that support decentralisation of activities, outsourcing, specialisation and division of labour. In particular, the emergence of a bundle of intertwined and interdependent innovations in technologies (ICTs) and organizations (networks), introduced such a dramatic transformation in the structure and dynamics of economic coordination that Chris Freeman (2009) coined the

[2] The term "knowledge society" is also used as a synonymous of "knowledge economy".

term of "ICT paradigm"[3] to depict such a pervasive change in the economic setting and in the way in which firms and organizations evolve, adapt and react to new emerging economic conditions. ICTs and networks developed in parallel and reinforced each other's diffusion, questioning the traditional, hierarchical way in which firms coordinated their productive and innovative capabilities.

More precisely, since the '90s, the rapidly expanding adoption of ICTs and the Internet as process innovations in the organization of productive activities is being associated with transformations in the conditions under which the production of goods and services takes place, and more precisely in the way in which economic agents interact each other in order to coordinate such production. The pervasive diffusion of computer-based ICTs have exerted strong pressure upon the governance mechanisms and the structure of formal organizations such as firms, fostering the adoption of administrative simplification, flatter hierarchical control and lean production processes. These transformations in both the technology and the organization of firms have been connected to the emergence of coordination structures alternative to the well-known vertically-integrated, hierarchical, and Fordist firm. Networks are increasingly viewed as structures that challenge formal organizations characterized by hierarchical control and well-defined boundaries.

The new gale of digital technologies has changed in depth not only the organization of corporations and the division of labour among firms, but also the organization of the generation of technological knowledge and of the introduction of new technological innovations. The introduction and diffusion of ICTs parallels in fact the emergence of new models of division of the innovative labour that is necessary to introduce new technologies. The generation of technological knowledge becomes a crucial activity where the borders of innovative firms need to be more and more porous so as to be able to access, absorb and use the distributed competence and the existing knowledge dispersed in the system.

In this context, ICTs and the Internet are perceived as centrifugal forces that foster decentralization, boundary crossing and networking because they make available technological tools for the efficient development of subcontracting, outsourcing and modular strategies (Kallinikos, 2009).

[3] The emergence of the so-called "ICT paradigm" has been paralleled by a broader set of changes introduced in the telecommunication industry itself. Impinging upon the centrifugal properties of new communication technologies and the diminishing importance of scale economies, regulators liberalize telecommunication markets worldwide, and in EU especially, enforcing the entry of new players which often deliver their communication services (such as, broadband services, TV on demand, IPTV, VOIP) precisely exploiting new communication technologies, of which the Internet is just the epitome. In this regard, the emergence of the "ICT paradigm" implies market changes both in the telecom market broadly speaking, and in the industry that make an intensive use of telecom and ICTs. In the former case, ICTs and the Internet are both a product and a process innovation that radically change the way in which communication services are delivered (e.g., the shift from copper cable to optic fibre; the introduction of wireless technologies) as well as the content of the services themselves (e.g., IPTV and VOIP). In the latter, ICTs and the Internet are mainly used as process innovations that change the way in which production is organized, product are manufactured and services delivered, for instance increasing delocalization and outsourcing, improving efficiency and control over production, relaxing the limits of physical proximity to deliver a given service.

This chapter focuses on innovation platforms that are emerging as new means to manage the recombinant generation of new technological knowledge and to coordinate the introduction of technological innovations exploiting the organizational opportunities opened up by technological innovation in ICTs and the Internet. At the same time, the innovation platform is itself an organizational innovation much diffused and adopted in the ICTs and Internet industry, for example by platform leaders such as Cisco, Microsoft, and Google. As a matter of fact, the growth of innovation platforms across a range of industrial sectors, with new ICTs and the Internet at the forefront, recently has attracted the attention of numerous studies of industrial economics and innovation economics, which have investigated the nature of these structures and how they influence the evolution of industrial sectors and innovation processes.

It is now acknowledged that the emergence of platforms has a profound impact on industrial dynamics, creating new forms of competition and laying the foundations for the creation of new relations of inter-organisational cooperation in the framework of innovation processes.

In particular, this chapter defines platforms as hierarchical networks, i.e. as networks in which the interactions do not emerge and evolve spontaneously, but in which key players (e.g., platform leaders and system integrators) exercise a guiding role on the behavior of the other actors, selecting the members of the platform itself and directing the behavior and the evolution of the system as a whole. A second distinctive element of these organizational forms is represented by the active search for knowledge complementarity and exploitation of variety (contrasted to mere agglomeration) between different activities, i.e. platforms are institutional arrangements to internalize knowledge spillovers and externalities. 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 some types of networks such as districts) (Gawer and Cusumano, 2002; Prencipe, Davies and Hobday, 2003; Consoli and Patrucco, 2008).

In this sense, the platform represents a significant organizational innovation, different to the integrated company, the market and the networks themselves with respect to both the coordination mechanisms and the assumptions about the characteristics of knowledge.

Integrating a complexity approach to organizations into economics of innovation, this essay traces the emergence of innovation platforms as both a result of technological innovation produced by the ICTs and as an organizational innovation much adopted in the same sector to achieve and sustain competitive position and growth of the players.

The chapter is structured as follows. Section 2 briefly recalls the basic tenets of the economics of ICTs, of which the Internet is credibly the most evident and widespread subset of technologies and applications. Section 3 articulates the structures and dynamics that characterize the new innovation and knowledge landscape after the advent of the ICT paradigm, the rise of networked organizations and the demise of the traditional, Fordist mode of innovation based on large, vertically integrated corporations. Section 4 is dedicated to understand the different features and processes that characterize platforms - a specific and nowadays pervasive type of networked organization - and by means of which platforms generate and manage innovation. Conclusions briefly summarize.

2. THE BASIC ELEMENTS OF ICTs

The distinctive element that characterizes the transition to the new knowledge economy is the provision of new knowledge-based activities that rely heavily on the quality and variety of advanced digital communication. The advent of digital technologies changes the context in which knowledge-based activities were traditionally coordinated, organized and provided in many ways. Let us now briefly recall the main characteristics on new information and communication technologies.

New information and communication technologies provide evidence for the Schumpeterian notion of gales of innovation (Antonelli, Patrucco and Quatraro, 2007). New information and communication technologies are characterised by the increasing convergence between and the integration of a variety of infrastructures, applications, tools and innovations each of which is generated in a wide range of industries and firms. In particular, such technological convergence[4] is driven by the introduction of a number of innovations such as Internet services, enhanced broadband fibre optics, ADSL, digital TV as well as UMTS opens up the possibility of integrating over the same means a variety of contents, services, technologies and applications. Contemporary ICTs are inter-networked and evolving, ranging from complex and integrated enterprises-wide system to distributed and ubiquitous technologies such as mobile email devices and weblogs (Edquist, 2003; Fransman, 2002; Fransman, 2006; Jones and Orlikowski, 2009).

As a result information and communication technologies, and the related technological knowledge, are both complex and fungible (Antonelli, 2003). On the one hand, new information and communication technologies are the outcome of the recombination of a variety of knowledge modules in the electronics, telecommunications, software, microprocessors and television technologies, each of which cannot be fully commanded internally by the firm and thus requires the coordination of technological complementarities within the broad ICT technological system. On the other, new communication technologies can be as a matter of fact applied to a large variety of manufacturing and service activities in both traditional and emergent sectors. The constant reduction in the price for ICT services, and especially telecommunications, in both nominal and hedonic terms, makes ICT-based products and services available at lower costs for a larger and larger range of users, with considerable effects in terms of profitability of adoption and improved productivity.

The integration of the array of interdependent, localized and sequential innovations, characterized by substantial indivisibility has been shaped by the implementation of: a) economies of localized learning due to the increasing specialization in specific technological areas, the advantages of network externalities and the gains from knowledge externalities; b) qualified user-producer and business-academic interactions; c) organizational innovations such as standardization committees, technological platforms, system integration,

[4] By "technological convergence" we mean the growing direction that characterize technologies originally belonging to different systems to progressively carry out similar tasks. In particular, this is the case for technologies such as voice (e.g., telephony features), media&video (e.g., music and television services), and data (e.g., productivity applications) that previously work separately and now, exploiting digitalization, share resources and interact with each other through single physical devices (e.g., tablets and smartphones). In this sense, technological convergence relies upon technological complementarities and network effects, and implies a networked product architecture. The Internet is itself a driver and a product of technological convergence, and probably the most powerful and pervasive result of such a convergence between new information and communication technologies (Fransman, 2010).

technological clubs and alliances to improve the dynamic coordination of the wide range of actors, products and technologies into a single working system and hence the complementarity, compatibility and interoperability of the variety of new localized technologies (David and Steinmueller, 1994; Shapiro and Varian, 1999; Antonelli, 2001).

In this context, since the early '90s, the new ICT paradigm described above have thus led to a rapid and radical transformation of the context in which firms compete, produce and innovate; ICTs made possible the emergence of global networks based on distributed coordination processes that sell worldwide customized products, manufactured and assembled in a variety of regions through systematic outsourcing of low-value activities, and instead retaining in home countries high-value and skill-intensive activities.

Firms can now rely heavily on ICTs to organize and coordinate their activity both locally and globally, with important effect on the economic organization of industries. On the one hand, flat and decentralized organizations made of a net of manufacturing and service units coordinate international flows of final and intermediary products by means of ICTs. Since the early '90s decentralized and networked organizations paralleled the traditional hierarchical and vertical structures because of the advantages made possible by the adoptions of ICTs. Work is often dispersed through temporary project teams that are cross-functional and dispersed, spanning geographic, temporal and cultural boundaries, and involving decentralized decision making. On the other, however, ICTs reinforce the power of a few global companies, now based on hybrid coordination processes that mix up distributed and hierarchical coordination. This is for instance especially true and relevant in the new service industry and in particular in the new knowledge-intensive-business-service sector (KIBS), such as software industries, and in high-tech industries more generally. The new knowledge-based industries are inherently global. They have a direct access to the international markets because of the foot-loose location of different branches and units across countries, and the rapid entry and exit in local markets through the adoption of outsourcing and networking strategies.

3. THE NEW ORGANIZATION OF THE GENERATION AND EXPLOITATION OF TECHNOLOGICAL KNOWLEDGE

The tradition of industrial economics and economics of innovation in the last century supported the thesis of the vertically integrated Fordist company, 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 it possible to obtain (Chandler, 1990; Penrose, 1959).

Following Chandler in his The Visible Hand (Chandler, 1977) and subsequent works like Scale and Scope (Chandler, 1990), Langlois (2003 and 2004) emphasizes the discontinuities brought by the appearance, by the end of the 19th Century, of the large, integrated corporation which replaced a previously existent fragmented and localized structure of production and distribution organized along Adam Smith's invisible hand of the market, and, subsequently, by the end of the 20th century, of a new upsurge of Smithian Forces (e.g., specialization, division of labour, outsourcing of production and the rise of distributed modes of organizing economic and innovative activities) that replaced the Chandlerian ones (vertical integration of production, scale economies, managerial control and the rise of the large corporation as the locus of production and innovation). Building upon this analysis Langlois articulates the Vanishing Hand Hypothesis according to which population and income growth

together with the accompanying technological changes (including improved coordination technology) have led to a new Enhanced Division of Labor, based upon high levels of specialization by function and coordination by markets.

This stream of literature questions not only the model of the integrated corporation, but also the traditional schemes of the organization of innovation. This implies that the linear and closed model, which saw innovation as a direct and almost automatic effect of the investments in R&D and learning-by-doing processes, must be replaced; not only must firms structure themselves so as to be able to draw advantage from the external knowledge available integrating it effectively with the knowledge produced internally (Chesbrough, Vanhaverbeke and West, 2006), but the industries and supply chains must reconfigure their boundaries and architectures to benefit competencies and technologies developed in other sectors (Jacobides, Knudsen, Augier 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 goes 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 co-ordination and the maximization of the creative contribution of the individual companies. This realization has opened the way to the analysis of the various forms (lesser or more extreme) of decentralization, specialization and division of innovative labour and production that emerged following the crisis of the organizational model of the vertically integrated corporation.

Thus on the one hand, 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 co-ordination mechanism of the division of labour in innovative activity (Arora, Gambardella and Rullani, 1998; Baldwin and Clark, 1997; Langlois, 2002). When a system is extensive and complex, and the interdependency between the elements and subsystems becomes particularly numerous, co-ordination through an integrated structure is almost impossible, and as is upheld, for example, by Baldwin and Clark (1997) and Langlois (2002) the organization of production and innovation through modular strategies is the most efficient way to organize and co-ordinate complex technologies and production systems.

According to this approach, companies can decide to adopt an integrated or modular organizational structure on the basis of the technologies and competencies that are the foundations for the introduction of 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. On the contrary, the fewer the number of elements that have to interact to generate an innovation, the simpler their co-ordination through the vertical integration of R&D activities will be (Chesbrough and Teece, 1996).

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 involved in the innovation process (Schilling, 2009).

The so-called loose coupling strategy does, however, show some limits. In particular, activities that demand exchanges of complex technological knowledge, such as those in high-tech, knowledge-intensive and computer-mediated industries, require the presence of integration mechanisms much more rigid, frequent and long term than a modular organization usually manages to guarantee (Schilling, 2009). If the activity demands an intense form of co-ordination and continuouity in time, the development process is conducted more efficiently within a more integrated and hierarchical organizational structure, which maintains closer integration between the partners involved. Also 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 spot, standardized market contracts and the benefits of long-term, collaborative interactions (Patrucco, 2012).

Moreover, it has been also highlighted that innovation systems are complex in many ways and characterized by non-decomposability (Consoli and Patrucco, 2011) – as opposed to the decomposability of pure modular systems. Innovation systems exhibit typical emerging properties as they are: a) inherently dynamic: 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; c) distributed as their dynamics is based upon the integration and inclusion of a large variety of agents characterized by dedicated skills and specific competences.

In this context the dichotomy between markets and hierarchies needs to be integrated by the appreciation of the pervasive emergence of a variety of hybrid forms of organization that impinge upon different combinations among markets and hierarchies. Two dimensions are relevant for this analysis. The appreciation of the distinction between interactions and transactions[5] and the identification and analysis of the variety of organizational forms that provide the coordination that is necessary to benefit from the division of labor, is crucial to go beyond simplistic dichotomies. As a matter of fact coordination can be either ex-ante or ex-post. It can be obtained by means of managerial action ex-ante, or by means of selective inclusion and exclusion, ex post. Pure interactions are organized by strong hierarchies. Pure impersonal transactions take place in perfect, impersonal, spot markets.

As Table 1 shows, we can identify a variety of hybrid forms based upon the mix between transactions and interactions that are placed on a continuum between pure transactions and pure interactions. The overlapping between interactions and transactions identifies an interesting area of complementarity where the two forms of organizing the division of labour complement each other. Here the type of coordination, whether ex-ante or ex-post plays a

[5] We can define interactions as personal and socially-based forms of coordination for economic activity that do not need formal agreements such as contracts and do not rely on a price system. On the contrary, transactions are defined as formalized and often standardized mode of coordination based on contracts and the price system. These two cases are clearly the two, theoretical extremes of a continuum where intermediate combinations of interactions and transactions open the scope for empirical analysis of different forms of coordination.

central analytical role. When interactions prevail, coordination is typically ex-ante. When transactions prevail, coordination takes place ex-post. This overlapping is relevant in a static context where technologies are given because of the pervasive role of information asymmetries, and most relevant in a dynamic context where the generation of technological knowledge and the eventual introduction of technological innovations takes place and is endogenous to the system. Let us consider first the static context and the dynamic one in turn.

TABLE 1. CROSSING THE BORDERS BETWEEN MARKETS AND HIERARCHIES

	PURE, PERSONAL INTERACTIONS WITH EX-ANTE COORDINATION	INTERACTIONS CUM TRANSACTIONS AND EX-ANTE COORDINATION	TRANSACTIONS CUM INTERACTIONS AND EX-POST COORDINATION	PURE, IMPERSONAL AND SPOT TRANSACTIONS WITH EX-POST COORDINATION
NO HIERARCHY				**PERFECT MARKETS**
WEAK HIERARCHY	OPEN SOURCE-BASED INNOVATION	CENTERED NETWORKS;	LONG-TERM CONTRACTS; 'OPEN' CONTRACTS; **VENTURE CAPITALISM**	
FLEXIBLE HIERARCHY		INTERNAL MARKETS WITHIN **CHANDLERIAN CORPORATIONS** ORGANIZED PLATFORMS	JVC, IN-HOUSE SUBCONTRACTING; CONGLOMERATE GROUPS; MULTINATIONAL CORPORATIONS	
STRONG HIERARCHY	**PERFECT FIRM**			

Within the perfect firm, characterized by strong hierarchies, coordination is achieved by means of pure interactions. Principals can trust agents because they can rely upon perfect information on their efforts and their competence. Interactions are complemented by incentives and monitoring mechanisms based upon ex-post assessment of the actual performances when instead principals do not have access to perfect information of the actual levels of competence and efforts of their employees. Old traditional mechanisms such as piecework and cottage work can be considered early forms of interactions-cum-interactions.

At the other extreme we find transactions-cum-interactions when pure transactions in the market place are impeded by the lack of relevant information upon the characteristics of the goods exchanged. Interactions complement transactions as they are the carriers of trust and loyalty. The parties can proceed in the transaction only if and when it is complemented by personal relations that warrant the actual quality and reliability of the goods.

Transactions-cum-interaction are typically found when transactions are reinforced by interactions such as in the case of long term contracts and 'open' contracts: transactions are no longer impersonal and no longer take place in spot markets. Partners in trade are personally identified and transactions are repeated over time. Here coordination, however, is left to the market place and the ensuing competitive forces: coordination is achieved ex-post also by means of selection and exclusion. Partners that are no longer able to meet the requested levels of performances are sanctioned with failure and exit (Bonazzi and Antonelli, 2003).

This view is further reinforced once we note that generally, most transactions that enable the division of labour both in product and factor markets characterized by the idiosyncratic characteristics of the good that are being exchanged and the complexity of their production processes are less and less undertaken under the umbrella of pure markets but take place only with the support of strong injections of organization and interactions along a continuum of hybrid forms between the two extremes of pure transactions within perfect markets and pure interactions within perfect hierarchies. Perfect markets and perfect hierarchies are typically found when the goods are perfectly homogeneous with highly standardized characteristics and low levels of variance in their production processes.

When we move from a static to a dynamic context, one where technological knowledge matters, hybrid forms play even a larger role. The recent advances in the economics of knowledge have made it possible to better qualify the intrinsic characteristics of the generation of technological knowledge as a recombinant and cumulative process characterized by high levels of uncertainty where existing bits of knowledge are indispensable yet sticky inputs together with competence based upon learning processes and research and development activities (Weitzman, 1996 and 1998; Von Hippel, 1998 and 2005).

This view has three major implications for the organization of the generation of technological knowledge:

i) in order to be able to generate new knowledge firms need to access existing bits of knowledge. Because of its irreducible tacit content, existing technological knowledge is sticky. High search, identification, decodification cost are necessary in order to use it again as an input into the generation of new knowledge. Knowledge transactions are not sufficient to access, understand and re-use -as an input- the relevant bits of existing knowledge. It is necessary to rely upon knowledge transactions implemented with knowledge interactions. User-producer interactions are necessary to reduce absorption costs. Perspective users of existing knowledge need to interact with its inventor in a structured framework that favours bilateral cooperation and reciprocal participation.

ii) because learning by doing and learning by using are at the origin of competence -a major input into the generation of new knowledge- principals need to stir the active participation and personal creativity of their agents. It is no longer sufficient to avoid shrinking and other opportunistic behaviours of agents. It is necessary to solicit the learning capabilities of employees. Interactions within hierarchical organizations must be implemented by incentive mechanisms –such as efficiency wages- based upon the actual contribution of employees to the increase of performances beyond their static levels. The members of an innovative organization must be motivated to learn and accumulate competence so to feed the recombinant generation of new technological knowledge.

iii) because of the high levels of serendipity and uncertainty that characterize the generation of technological knowledge not only with respect to the timing of the outcome, but also with respect to its actual content and the constraints caused by the diseconomies of scope, firms have discovered the advantages of selective partnership to exploit new technological knowledge when its application exhibit high levels of variance with respect to the core business. The exploitation of such new technologies is implemented by means of the creation of joint ventures with other firms endowed with localized complementary competence that favour the introduction of innovations and their incremental variations so as to reduce coordination costs. Here, once more, ex-post coordination mechanisms complement structured interactions.

Hybrid forms are necessary to generate new technological knowledge and introduce and exploit technological innovations as interactions-cum-transactions are necessary within hierarchies to mobilize the learning capabilities of the agents and transactions-cum-interactions are necessary to access the existing bits of existing knowledge and appropriate the benefits of unexpected outcomes of the knowledge generation process.

A quote from Adam Smith is useful to grasp the vital role of interactions-cum transactions within hierarchies: "Whoever has been much accustomed to visit such manufactures, must frequently have been shewn very pretty machines, which were the inventions of such workmen, in order to facilitate and quicken their own particular part of the work. In the first fire engines -this was the current designation for steam engines-, a boy was constantly employed to open and shut alternately the communication between the boiler and the cylinder, according as the piston either ascended or descended. One of those boys, who loved to play with his companions, observed that, by tying a string from the handle of the valve which opened this communication to another part of the machine, the valve would open and shut without his assistance, and leave him at liberty to divert himself with his play-fellows. One of the greatest improvements that has been made upon this machine, since it was first invented, was in this manner the discovery of a boy who wanted to save his own labour" (Smith, 1776). The accumulation and valorization of the competence based upon learning by doing and learning by using within a firm is limited if not inhibited by the lack of appropriate incentive mechanisms that appreciate, stira ns support the active contribution of employees (Arrow, 1974).

A clear example of the relevance of transactions-cum-interactions is provided by the new understanding of the central role of the interactions that follow a transaction where a vendor provides a customer with a new product. The benefits of learning by using are faster and larger when customers after the transaction –as users- can interact with competent producers that sold them the new product so as to improve it and at the same time make its use easier and more effective. User-producer interactions that parallel and complement vertical transactions are a major source of technological knowledge for both parties (Von Hippel, 1998 and 2005).

These hybrid forms take place in contexts that are characterized by weak hierarchies and organized markets. Very relevant for this chapter, interactions-cum-transactions and transactions-cum-interactions are typically found within centred networks and especially structured platforms. In these hybrid forms the coordination that is necessary to achieve and integrate an efficient division of labour is defined ex-ante and implemented by managers that try and implement a hierarchical control of the recombinant knowledge generation process and of its effective exploitation. This confirms the importance for the innovative firm to build and be embedded in networks and for economics to appreciate the systemic character of the structures into which the division of innovative labour takes place (Lane et al., 2009; Antonelli, 2011).

Platforms are characterized not only by transactions-cum-interactions and interactions-cum-transactions but also their dynamic membership within a changing architecture that make it possible to implement and operationalize the mix between ex-ante and ex-post coordination. Membership in platforms is not permanent: inclusions and exclusions do take place at all times. The actual membership into the platform is in fact the object of continual assessment, monitoring and selective renewal. The division of labour within platforms is based upon stages at the end of which the actual contribution of each member is assessed and valued critically both in terms of results and efforts. The parties agree ex-ante upon the procedures

that will be applied in order to monitor the results and the efforts. Exclusion takes place ex-post as a result of the assessment. The architecture of the platform, moreover, is intrinsically dynamic also with respect to the role of each member that may shift in terms of degrees of centrality. Lazy, opportunistic or less-competent-than-expected members may gradually shift from high levels of centrality into marginal roles that lead to eventual exclusion. Competent members that are able to contribute more than expected may, on the contrary, move from peripheral roles into more central ones. Open contracts, where the parties agree upon the procedures rather than on actual contents combining intellectual property rights with contractual law enable the organization to change shape, structure and membership and play a central role in this context (Hagedoorn and Hesen, 2007).

The identification of the historic process that led to the introduction of the platform is most relevant to grasp its key features. Platforms can be regarded as the outcome of the evolution of the bilateral outsourcing of given inputs into the creation of a frame of multilateral cooperation for the distributed participation to the generation and exploitation of new technologies, based upon the intensive use of ICTs and flexible, long-term contracts. One of the first introduction of platforms took place for instance in the last decades of the XX century in the automobile industry where car manufacturers experimented the integration of their component suppliers into the design of new models changing radically the traditional sequence by means of which suppliers were requested to manufacture their components after the design of the model by the car company. The systematic use of large data banks to which all the selected partners could participate played a central role in the evolution of the new organizational procedure (Patrucco, 2013).

According to our analysis, and from an organizational viewpoint, platforms can be considered a new case of a dynamic hybrid form based upon interactions-cum-transactions and transactions-cum-interactions with changing architecture and membership (Consoli and Patrucco, 2008, 2011; Patrucco, 2012).

The next section is dedicated to understand the different features and processes that characterize platforms and by means of which platforms generate and manage innovation.

4. VARIETY AND DYNAMICS OF PLATFORMS

Given the growing spread of the phenomenon in various industrial sectors, platforms stir an intense debate across disciplines.

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 referring to models for the coordination of complementary components such as computers. Rochet and Tirole (2003) first went beyond the physical features of artefacts thinking of platforms as a design concept.

In general, management scholars connect platforms to the challenges and the strategic implications associated to the emergence of open systems for production, exchange and govern competencies (Gerstein, 1992; Garud and Kuramaswamy, 1996; Ciborra, 1996; Ethiraj and Levinthal, 2004; Jacobides and Billinger, 2006). In the policy realm innovation platforms are looked at as a key reference model for the creation and management of mixed (i.e. public and private) coalitions (European Commission, 2004).

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

Consoli and Patrucco (2008 and 2011; Patrucco, 2012) stress instead the organizational implications of platforms articulating the notion of "innovation platforms" as hybrid coordination modes that combine both interactions and transactions with hierarchical coordination and management of the networks. Innovation platforms are strategic organizational vehicles for coordinating specialized and complementary actors.

Despite the differences that a comparison between different approaches and perspectives necessarily implies – an exercise that would be out of the scope of this chapter – 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. Innovation platforms however emphasize, firstly, the coexistence of both market transactions and collaborative interactions, and, secondly, that they produce an outcome – an innovation – that is the result of collective learning and alignment of investments.

In these structures a variety of agents participates to 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. The point, though, is that such differences across agents matter to a great degree. In turn, the architectures in which they operate are flexible and can be configured in different ways for different uses, very much akin to computer platforms. A central component of the rationale underpinning platforms is maximising the variety of contributions stemming from a variegated knowledge base while maintaining coherence though a minimum level of hierarchy. As will be discussed further, innovation platforms are purposefully 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. At the core of the logic of a platform stand three powerful sources of increasing returns: economies of scale due to increased volumes of throughput; economies of scope due to lower costs of producing variations around the core product and services of the platform; and economies of system, that is, the creation of dedicated control procedures to improve utilization of the installed capacity. Another crucial characteristic of platforms is the functional relation in which services and manufacturing activities stand to one another (Suarez and Cusumano, 2009). The provision of some services, in fact, enables closer customer-producer interaction and opens up important feedback mechanisms useful to the effect of adapting the organisation of the platform, or some of its components, towards emerging features such as unmet customer needs, skill gaps, future product developments.

Relevant dynamics within platforms span technological and organisational levels, and bear upon both the static and the dynamic coordination of knowledge. From a static viewpoint, platforms connect and integrate activities and capabilities of relevant agents within an industry, thus supporting specialisation and favouring 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 (Antonelli, 2014).

Let us now draw attention to the structural and dynamic properties that characterize innovation platforms.

The coupling of two distinctive characteristics of platforms: a) their role whether finalized to support the generation of technological knowledge or its exploitation, and b) the levels of exclusivity of membership make it possible to identify the basic elements of a typology.

Closed platforms are characterized by substantial membership exclusivity. In closed platforms the members belong to a single platform. In open platforms members are active in many different platforms. Generative platforms are mainly finalized to support the generation of new technological knowledge, while exploitation platforms are implemented to support the exploitation of knowledge after its generation, and its incremental development.

TABLE 2. THE DYNAMIC VARIETY OF PLATFORMS

	EXCLUSIVE MEMBERSHIP	NON-EXCLUSIVE MEMBERHIP
	CLOSED PLATFORMS	OPEN PLATFORMS
KNOWLEDGE GENERATION PLATFORMS	HIGHER STABILITY LOWER RISKS OF OPPORTUNISTIC BEHAVIOR	HIGH PERFORMANCES WITH SUBSTANTIAL FRAGILITY
KNOWLEDGE EXPLOITATION PLATFORMS	STABILITY WITH MAJOR ASYMMETRIES IN DEDICATED KNOWLEDGE APPROPRIATION	GENERAL PURPOSE TECHNOLOGIES FRAGILITY

This typology of platforms is relevant to grasp their performances and dynamics. Closed generation platforms are likely to exhibit higher levels of stability and loyalty in partnership, lower risks of opportunistic behaviour and hence higher levels of stability. Open generation platforms are likely to perform better in terms of rates of generation of technological knowledge as they can draw from a wider variety of competencies that are fed by a larger variety of interactions of the members that are able to transfer their tacit knowledge from one platform to another. Open generation platforms are characterized by higher fragility as the members may have larger opportunities to leave one platform to enter other(s). Open exploitation platforms reduce asymmetries in the distribution of the rents stemming from knowledge as non-exclusivity increases the bargaining power of exploiters and reduces the monopolistic strength of 'inventors'. Open exploitation platforms at the same time may offer larger opportunities of knowledge exploitation when it has high levels of fungibility and as such it can be applied to a variety of different fields. Typically open exploitation platforms are found when the scope of application of a technology is large. Closed exploitation platforms are found with technologies that have a limited scope of application. Again it seems clear that open exploitation platforms exhibit lower levels of stability. Closed exploitation platforms favour the bargaining power of 'inventors' and are better suited to support the appropriation of technological innovations with a limited range of applications. Closed exploitation platforms are more stable in time than open exploitation platforms that are far more fragile.

In this context, inclusion in collective structures for knowledge sharing does not diminish the uncertainty associated with competition in fast-changing contexts but rather changes the nature of such uncertainty. To be viable infrastructures like innovation 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 the implementation of major technical changes generates new opportunities for learning but in so doing also leads to skill shortages. For instance, empirical works such as those by Brynolfsson and Hitt (2000) demonstrate that the large-scale diffusion of Information and Communication Technologies (ICTs), often the backbone of innovation platforms, stimulates the emergence of new tasks and competencies required. In turn, where new knowledge comes from and the costs for this knowledge to be absorbed, integrated and used by different members of the network depends on the degree of openness of the platform.

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, and multisided learning.

The view of platforms as collective structures bears important consequence for management of platforms and centred networks in that it stresses the problem of inclusion and exclusion in the network and highlights the major role played by those firms that are the leaders of the network.

Concepts like architectural knowledge (Henderson and Clark, 1990), platform leadership (Gawer and Cusumano, 2002), architectural capability (Jacobides, 2006), or that of system integrators (Prencipe, Davies and Hobday, 2003) have been introduced recently to describe precisely that decisive capacity, possessed by the platform leaders, to co-ordinate 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.

As a matter of fact the main object of the platform leader is to drive the innovation process in the industry and this cannot be achieved without loosening the collective structure and goal during the continuous adaptation to the fast-changing market conditions.

In this regard, Iansiti and Levien (2004) talked of three most important objectives that a network leader is facing: 1) to maintain platform integrity and the compatibility between complementary products; 2) to manage technological innovation within the platform without losing backward compatibility with existing products and technologies; 3) to preserve the leadership against other firms acquiring power within the platform. These two authors labelled as “keystone” those leaders able to benefit from and at the same time to generate significant externalities within the platform in order to sustain the collective performance of the network. While “dominator” leaders behave mostly in a predatory way, integrate vertically and horizontally the network and seek to appropriate most of the value produced by the network, “keystone” leaders achieve the mix between value appropriation and value sharing between platform’s partners.

Gawer and Cusumano (2002) argued that the main problem of platform leaders can be identified in two key features of contemporary platforms: 1) the increasing interdependency of products and services; 2) the increasing ability to innovate by more actors, especially in the high-tech sectors. The combined effect of these two elements determines that the evolution

and improvement of one element in the product/service/organization of the platform is complementary and interdependent to the development of all others elements.

The success of the platform occurs only when the diverse incentives and capabilities of a variety of heterogeneous actors are organized so as to display a character of alignment and convergence. In facts, only the convergence of a plurality of complementary actions aligned though sequential chains of user-producer relations can shape the actual direction and speed of the process. For instance, one of the main problems of Intel was precisely to create the appropriate set of incentives for hardware and software producers to introduce innovations that parallel improvements in microchips.

The changing architecture of networks plays a key role here. The inclusion and exclusion of specific actors, characterized by idiosyncratic productive and innovative capabilities, as well as incentives, change the strategic behaviour of the coalition, its objective and the likely actions through which these can be achieved. The need for dynamic coordination, i.e. coordination at each point in time of the heterogeneous actors embedded in the network is clear, if the goal is to be the successful realization of a common innovation. In such a systemic context, dynamic coordination requires some forms of hierarchical organization and yet, for the complexity involved in the system, no single firm commands both the technological and managerial resources necessary to make such coordination effective technologically and efficiently in terms of the coordination costs. Some intermediate forms of organization are required and it is likely that the implementation of networks centred on key firms and their strategic action emerges as more appropriate than extreme solutions such as market exchange and vertical integration. Innovation platforms as hybrid organizational forms emerge precisely as the appropriate strategy in order to make possible bureaucratic organizations reacting to improvements in product or services by acquiring externally the know-how necessary to innovate.

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.

Also empirical evidence about platforms shows that different firms developed different technologies as well as modelled their strategic decisions fine-tuning their choices on the base of the characteristics of their environment and of internal and external resources available.

Intel and Microsoft are for instance firms that largely benefited from both external collaboration and competition, making their innovations crucial elements of their platforms. Again, Intel and Cisco, despite their different dimensions, supported the acquisition of external knowledge in those technologies where internal competencies were less developed; this strategy enlarges the scope of their platforms and especially in the case of Intel developed a modular and open platform architecture. Microsoft instead can be described as a "dominator" firm rather than a "keystone" or a platform exploiting its innovation system and in many cases fully appropriating its value without supporting collective dynamics of knowledge and on the contrary developing a closed and much hierarchical network architecture (Bresnahan, 2002; Gawer and Cusumano, 2002; Casadesus-Masanell and Yoffie, 2005; Gawer and Henderson, 2007). Smaller firms such as Palm and DoCoMo show further diversity and specificities. Finally, a special case such as Linux, although not a "pure" company, demonstrates the power of collective dynamics based on collaboration, exchange of external knowledge and the sharing of common goals and objective in the development of platforms (Eisenmann, Parker and Van Alstyne, 2011; Tee and Gawer, 2009).

Table 3 summarizes the main elements of six different platforms in the ICTs sectors according to three main dimensions (Gawer and Cusumano, 2002); it shows the variety of their strategies and characteristics.

TABLE 3. PLATFORMS STRATEGIES AND CHARACTERISTICS IN THE ICT SECTOR

Key platform dimensions *Firm*	SCOPE	ARCHITECTURE	EXTERNAL NETWORK
INTEL	Exploration of external resources Collaboration with external producers of complements	Modular structure Open interfaces Collaboration on standard setting	Long-term collaborations with complements producers Value sharing
MICROSOFT	Exploitation of internal core competencies	Closed structure Proprietary interfaces and standards	Horizontal and vertical competition Horizontal and vertical integration of producers Value appropriation
CISCO	External knowledge exploitation and acquisition	Mixed structure Open standards and interfaces Proprietary development of new technologies Proprietary software	Long-term collaborations with complements producers Horizontal and vertical integration of producers
PALM	Exploitation of internal core competencies on hardware and software Collaboration with external producers of applications	Modular structure that facilitate complements development Proprietary technologies on OS Open interfaces on applications	Long-term collaborations with complements producers Strong user-producer relations Collective learning
DOCOMO	Exploitation of internal resources External collaborations	Modular structure Open interfaces and standards	Long-term collaborations with producers
LINUX	Strong exploration of external resources	Open standard	Collective learning

Source: our elaboration on information provided in Bresnahan, 2002; Gawer and Cusumano, 2002; Casadesus-Masanell and Yoffie, 2005; Gawer and Henderson, 2007; Eisenmann, Parker and Van Alstyne, 2011; Tee and Gawer, 2009.

5. CONCLUSIONS

Platforms are a major organizational innovation in knowledge governance that exploit the advantages of ICTs in terms of improved flexibility, enhanced control and efficient networking. Platforms are becoming a crucial tool for implementing and supporting knowledge governance both at the firm and the system level. At the firm level the creation and the inclusion in a platform is essential to manage the knowledge generation process widening the range of competences that can be accessed and integrated into the recombination. Platforms make it possible to increase the amount and the quality of external knowledge that can be used by each firm. As such the platforms enable the drastic reduction of the generation of new technological knowledge and of the introduction of technological innovations. Firms can substitute cheaper external knowledge to expensive research and development activities. The advantages of knowledge cumulability and non-exhaustibility are better exploited. From this viewpoint platforms are an emerging organizational innovation that is likely to substitute the Chandlerian corporation.

Platforms make it possible to better organize the valorization of technological knowledge after its generation reducing uncontrolled leakages and exploiting economies of scope with the systematic internalization of potential complementarities with a wide range of partners.

At the firm level platforms make it possible to command the endogenous creation of knowledge externalities and in so doing make it possible at the same time: i) to shrink the absorption costs that stem from a variety of activities such as search, screening, identification, decodification and re-codification that are necessary to actually use external knowledge as an input into the generation of new knowledge, and ii) to increase the command of the knowledge exploitation processes. This leads to fastening the rate of introduction of technological innovations and to increasing their market value.

The support to the diffusion of platforms at the system level may become a major tool of an economic policy aimed to increasing the quality of knowledge governance. First, platforms can become a key element of national and regional innovation systems. In an evolutionary perspective, the notion of innovation system has been introduced in order to stress the role that the variety of actors and the connections among those actors play in the generation of new knowledge and innovations. The implementation of platforms within innovation systems emphasizes that both the active selection of the members of the innovation system and their structured coordination should become a major goal for the policy maker in order to support the creation and diffusion of new knowledge and the introduction of innovations (Patrucco, 2014). The active selection of the members of the system should be centred around the exploitation of knowledge complementarities, minimizing redundancies of endowments, skills and competencies. In this regard, the active selection of the members and their structured and dynamic coordination enable to overcome the limits of the spontaneous coordination of innovative efforts within networks..

Furthermore, the identification of potential platforms and the intervention of public authorities to stir their implementation may help the economic system to fasten the rate of generation of new technological knowledge and of the introduction of technological

innovations. The integration of public procurement with the active support to the creation of platforms on the supply side can become a very effective frame to improve the capability of the system to command the endogenous creation and exploitation of knowledge externalities using public procurement an a powerful incentive.

Because, like a glass mirror, platforms make it possible to multiply the light of knowledge candles, a system where public policy has been able to implement a variety of platforms is likely to experience better performances in the generation of new technological knowledge at lower unit costs.

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