

INDUSTRIAL COMPETITIVENESS AND INTER-FIRM CO- OPERATION: AN ANALYSIS OF STYLISED MODELS OF INTER- FIRM NETWORKS

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Abstract

The article discusses the institutional diversity of inter-firm networks, suggesting that they should be understood as institutional forms conditioned by the characteristics of technologies mobilised to make feasible the production in these environments. The analysis is organised in three stages. First, an analytical framework is developed, introducing some elements related to structural characteristics of these networks and to the determinants of network competitiveness. Then, some elements associated with the technological complexity of the environment are used to characterise different “stylised models” of inter-firm networks. Specifically, four kind of networks are identified: traditional networks, technology structured networks; complex technology networks and technology-based networks. The main characteristics of those “stylised models” are presented, emphasising the determinants of network competitiveness in each situation. Finally, a conclusive section identifies some investigation lines to be explored in the future.

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Introduction

The evolutionary approach in Industrial Economics has recurrently discussed the characteristics of inter-organisational configurations adequate to face the instability and complexity of the economic environment. These studies show the emergence of multiple forms of productive and technological co-operation among firms, seen as inter-organisational set-ups that allow a better facing of environmental changes. The intensification of co-operative links has persuaded researchers to focus on the complex interdependencies between firms in the economy through the use of a 'network approach' (Grabher, 1993; Hakasson, 1989; Axelsson and Easton, 1992; Karlsson and Westin, 1994). Inter-firm networks have been conceived as institutionally structured arrangements that enable an efficient organisation of economic and technological activities, through the co-ordination of systematic links that are established among firms. They have been analysed as an (inter)organisational form suitable for the built of flexible systems of production and for the integration of complementary competencies that are required in the innovation process.

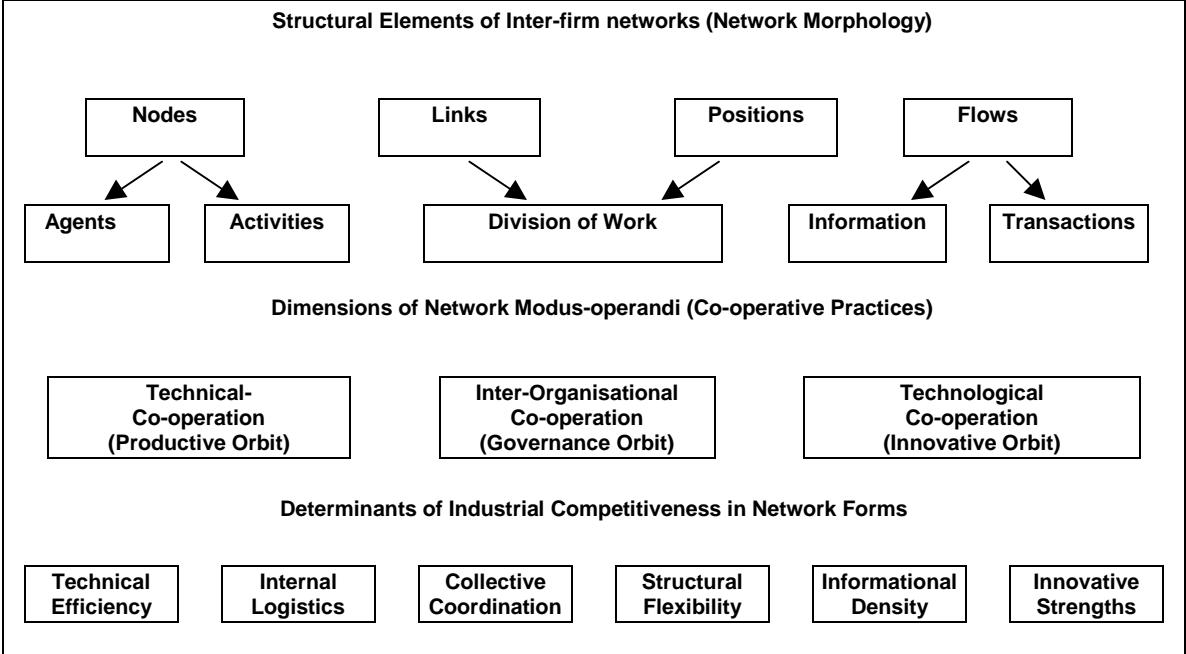
The article discusses the institutional diversity of inter-firm networks, suggesting that they should be understood as institutional forms conditioned by the characteristics of technologies that have to be mobilised to make feasible the production in these environments. The analysis developed tries to qualify the concept of 'embeddedness' (Grabher, 1993), in order to consider how technological patterns affect the internal morphology and the co-ordination mechanisms of inter-organisational arrangements. The analysis is organised in three stages. The first (Section 1) involves the built of an analytical framework to evaluate the impacts of these arrangements in terms of industrial competitiveness. The second (Section 2) involves the definition of objective criteria to map the institutional diversity of these networks, specifically associated with the 'complexity' of the technological environment in which they are inserted. The third (Section 3) involves the characterisation of 'stylised models' of inter-firm networks with basis on the criteria previously defined. These models are evaluated with basis on the analytical framework previously presented, in order to identify the determinants of competitiveness in each situation.

1. Analytical Framework

The concept of 'network' has been increasingly used in economic analysis. In order to avoid the risk of misunderstanding, the concept of 'inter-firm networks' must be defined in a rigorous way. In this sense, the analytical framework developed tries to incorporate elements associated with the morphological structure of these networks as well as the main impacts of co-operation practices in these arrangements and the main determinants of network competitiveness (see Figure 1). 'Network', by itself, is an abstract notion referring to a set of nodes, to the positions occupied by them and to the various links that connect these nodes. We can also relate the structure of a network to internal flows that are interchanged between nodes through specific links. The network approach can be extended to the economic relations between firms, being associated with structures in

which the generic morphological elements of 'networks' - nodes, positions, links and flows - assume a specific character. In this approach, the network nodes can be related to firms with specific characteristics, while the relations that articulate them contain some tangible or intangible element of capital. In fact, we can observe the presence of firms with different characteristics inserted in these networks, which make joint investments and co-ordinate, with view to certain aims, their productive and technological activities. Those firms have asymmetrical characteristics - related to specific competencies - which affect the possibilities of a mutual interaction among them. These arrangements also imply certain investment efforts, resulting in specific sunk-costs to the relation and in rigidities that reinforce the links among firms along time. Network analysis tries to identify the relevant organisational characteristics of the agents involved, as well as to map the relationships established among them.

Figure 1 - Analytical Framework



Inter-firm networks consist not only of actors and relationships, but also of certain activities and resources. In fact, we can observe the integration of multiple activities (production, commercialisation, R&D etc) at the network level, generating an interdependence that reinforces the cohesion of the arrangement. The functional interdependence between network members can be related to a structured 'division of work' connecting different activities performed by them. We can also stress the relevance of some 'internal flows' that connect the agents inserted in these networks. These flows involve two-way exchange processes that form the backbone of the networks (Easton e Lundgreen, 1993). They are responsible for the generation of internal stimulus that induce the strengthening and transformation of the structure over time. They involve not only tangible assets - including transactions of inputs and products - but also intangible assets - such as information and tacit knowledge - that reinforce the connections and interdependencies between network members.

The concept of inter-firm networks highlights the importance of structured sub-systems in the modulation of industrial dynamics (Bandt, 1990).. They have a relative autonomy to

outside forces, as well as a certain grade of self-organisation, deriving from external stimuli as well as endogenous forces. A rigorous characterisation of these networks requires the identification of the relevant dimensions of co-operative links between their members. Specifically, three dimensions must be stressed: a technical co-operation related to the productive practices adopted at the network level; an inter-organisational co-ordination related to characteristics of the network as a governance structure; and a technological co-operation specifically related to the innovative efforts that permit the integration of competencies and the amplification of learning gains among network members.

In the productive orbit, it is important to consider the tools mobilised to raise productive efficiency and flexibility at the network level. Specifically, it is important to explain how the consolidation of a functional specialisation among network members generates technical gains which creates competitive advantages to them. Considering the complexity of productive chains in inter-firm networks, some aspects are particularly relevant. First, it is important to analyse the characteristics of products generated and processes employed at the network level, identifying technical gains associated with economies of scale and scope. Another aspect involves specific mechanisms used to co-ordinate productive flows in those arrangements. The more complex a network structure is - in terms of its internal logistics - the more necessary will be an efficient co-ordination of the activities performed. The diffusion of just-in-time practices and other inter-organisational techniques at network level can be seen as examples of this kind of co-ordination. Besides the generation of scale/scope economies and the improvement of network logistics, there are also other gains that can be observed at the network level. Some of these gains must be emphasised. First, we can mention the increase of labour and capital productivity at the network level due to the specialisation of their members. Second, there are improvements in the quality of products generated, resulting from the adoption of certification and other procedures among network members. A negotiate definition of technical standards at the network level can also be obtained, as well as the customisation of products generated according to the needs of customers, integrating technical competencies of network members. The increase of product flexibility, through the generation of a product mix that reinforces the ability to deal with market differentiation and volatility is another font of gain at the network level.

In the organisational orbit, it is important to identify how the co-ordination of strategic actions of network members can be obtained, through the consolidation of a governance structure that makes easier the adaptations required in face of market changes. More than a 'idealised' (hybrid) form of governance, localised between the integrated firm and the atomised market, inter-firm networks could be associated with co-ordination mechanisms that have their own specificity, related to a contractual basis which orients interactions between network members and to a certain level of mutual trust (Humphrey and Schmitz, 1996) that can be found in inter-firm relationships. It is supposed that the process of co-ordination is strongly affected by the relative size of network members, by the internal stratification of network structure and by the centralisation of networks' strategic decisions, as well as to mechanisms of conflict solving that might be mobilised at the network level. In this sense, the presence of institutions responsible for the co-ordination of 'joint actions' should also be stressed as an important element of these arrangements. As part of the these co-ordination procedures, we must also consider the importance of a contractual basis - more or less formalised - which rules the interactions established among network members. This contractual basis is supposed to include incentive mechanisms involving the sharing of productivity earnings and quasi-rents, as well as specific instruments to solve networks' internal conflicts. Nevertheless, in dynamic environments the assembling

of a formalised contractual basis becomes more problematic. In this case, we should also consider the consolidation of values, rules and non-formalised behaviour codes among network members, which reinforce the internal cohesion of the structure over time.

In the technological orbit, we can associate inter-firm networks with the creation and circulation of knowledge and information, generating a collective learning process that widens the innovative potential of the arrangement, through the integration of complementary competencies and skills. The collective learning process observed at the network level involves the incorporation of individual learning and skills of firms to a social pool of knowledge and competencies available to network members. In this process, positive externalities are generated, being related to the potential utility of the knowledge shared by network members. This perspective stress the importance of interactive learning mechanisms institutionally conditioned through the mediation of the network . Four main learning mechanisms might be underline at the network level. First, we can observe the creation of technological knowledge intentionally developed in co-operation, with basis in joint R&D activities performed by network members, which raises the productivity of these activities through the exploitation of scale economies and specialisation earnings. Second, the competencies of network members tend to be upgraded in a co-ordinate way. Third, there are specific mechanisms of knowledge circulation inside the network that permits a reduction of innovation lags and an acceleration of incremental innovations. Fourth, we can observe stimuli to the diffusion of technological innovations among network members due to the close links - productive, technological etc. - established between them.

Another issue of the analysis involves the connections between the consolidation of inter-firm networks and the strengthening of industrial competitiveness. The impacts of these networks in terms of industrial competitiveness can be associated with the increase of profitability and market power of their members. Camagni (1991), for instance, identifies the following gains: (i) synergies and economies of scale in production, marketing and R&D; (ii) scope economies and product differentiation; (iii) cross-fertilisation and development of complementary competencies; (iv) fast-reaction capabilities to face external shocks; (v) formation of new kinds of entry barriers (associated with proprietary standards, for example); (vi) control over innovation assets. Some of these gains seem to be particularly important in complex and dynamic environments where the possibility of mobilising complementary assets and competencies - in order to avoid the costs of search, screening and decoding complex information and the uncertainty elements involved - increases the competitiveness of network members. Otherwise, an effective control over the development trajectory of assets and technologies can often be obtained through the built of these networks.

The main issue of the analysis is the nexus between the consolidation of industrial networks and the strengthening of industrial competitiveness. Despite the recognition of relevant connections between the fonts of competitive advantage and the effects of inter-firm co-operation, the literature about industrial competitiveness has faced some discomfort when it tries to discuss these connections in a more rigorous way. Probably, part of these difficulties can be attributed to the diversity of determinants of competitive advantage in each industry and to the diversity of institutional forms of inter-firm co-operation that prevail in them. The multiplicity of institutional forms of inter-firm co-operation makes extremely difficult the identification the elements that should be correlated to fonts of competitive advantage. In the analysis developed inter-firm networks are articulated to some attributes of inter-firm co-operation that strengthens the competitiveness of network members. Specifically, these attributes can be characterised

as 'internal proprieties' of the arrangements that make easier or hinder the absorption of competitive pressures, acting as important determinants of network competitiveness. Table 1 summarises the internal proprieties of inter-firm networks. Competitive pressures would define the relative importance of each one of these internal proprieties while source of competitive advantages to network members. We can also suggest that these proprieties strongly condition the economic performance of inter-firm networks. Thus, the identification of the relative importance of these proprieties can be seen as an important step to evaluate network competitiveness in empirical situations.

Table 1 - Networks Internal Proprieties

Propriety	Characteristic	Critical Elements
Proprieties associated to Productive Co-operation		
1) Technical Efficiency	Technical- gains generated at the network level which impact productive costs, based on a functional specialisation of suppliers.	<ul style="list-style-type: none"> . scale and scope economies . external economies generated . productivity and quality gains . standardisation gains
2) Productive Logistics	Adjustments in network internal logistics in face of market evolution, with the elimination of bottlenecks in the supply chain and reduction of time-lag adjustments.	<ul style="list-style-type: none"> . supply chain logistics . diffusion of just-in-time practices . systems integration gains . modularity gains
Proprieties associated to Organisational Co-operation		
3) Collective Co-ordination	Level of network centralisation associated with the presence of specific firms or institutions with the function of co-ordinating internal flows.	<ul style="list-style-type: none"> . internal hierarchy of the network . relative size of network members . incentive mechanisms adopted . forms of joint actions
4) Structural Flexibility	Capacity of adapting network structure according to environmental stimuli and competitive pressures, trough the process of entry and exit of network members.	<ul style="list-style-type: none"> . entry and exit rules . frequency of transaction . temporal horizons of relations . contractual basis of inter-firm relations
Proprieties associated to Technological Co-operation		
5) Informational Density	Capacity of co-ordinating informational flows and disseminating relevant information among network members..	<ul style="list-style-type: none"> . complexity of information transmitted . information systems . communication infra-structure . network codification procedures
6) Innovative Strengths	Innovative competencies of network members based on interactive learning mechanisms and on the agglutination of multiple competencies and skills through formal efforts.	<ul style="list-style-type: none"> . joint R&D efforts . co-development practices . R&D specialisation patterns . mechanisms of technology transfer

Six proprieties of inter-firm networks can be emphasised. Two proprieties can be associated with the productive orbit of the network: the increase of technical efficiency and the improvement of productive logistics. The increase of **technical efficiency** can be related to scale and scope economies obtained at the network level, as well as others impacts in terms of the increase of quality and productivity. It refers also to the diffusion of productive best practices among network members. We can suppose that the stronger are the competitive pressures to the reduction of costs, the more important will be the reinforcement of this propriety at the network level. On the other hand, the improvement of **productive logistics** can be related to the timing of network answers in face of market signals. These adjustments involve not only the co-ordination of productive flows inside the

network, but also some requirements related to the quality of products generated. In dynamic environments, network logistics should be nimble enough, allowing an immediate reaction in face of market changes. This propriety could also be related to the diffusion of just-in-time practices at the network level and to other factors responsible by the internal flexibility of the network.

Two other proprieties can be associated with the governance orbit of the network: the strengthening of collective co-ordination and the improvement of structural flexibility. The **collective co-ordination** refers to specific characteristics of the governance structure of the network that make easier the integration of actions and efforts of network members. This propriety can also be associated with the presence of firms or institutions that co-ordinate strategic and operational actions adopted by network members. It also involves the nature of collective actions taken by networks' members, as well as the principles of 'mutual trust' presented in network environment. On the other hand, the notion of **structural flexibility** refers to re-arrangements of the functions performed by network members, as well as to changes of network structure. This propriety involves adjustments of network internal morphology according to environmental stimuli, incorporating new agents or, alternatively, demobilising resources compromised with activities that stop to be performed at the network level. It is supposed that, in dynamic and volatile environments, the network should be able to modify quickly its structure, operating from a core of enterprises, around which gravitate other agents that could be absorbed or excluded according to environmental stimuli.

Two other proprieties can be associated with the process of technological co-operation – related to an innovative orbit - at the network level: the improvement of informational density of the network and the strengthening of innovative capabilities of their members. The improvement of **informational density** refers to the complexity of informational flows and to the 'socialisation' of knowledge among network members. This propriety can be associated with the existence of communication structured channels between network members and with the intensity of information flows which circulate inside them. It assumes great relevance in complex and volatile environments that are permanently issuing signals that must be captured and interpreted by economic agents. On the other hand, the improvement of **innovative strengths** refers to the integration and co-ordination of technological efforts performed by network members. This propriety refer to the generation of innovations at the network level, integrating multiple competencies of their members in joint projects or exploring the possibilities of obtaining relevant innovations through interactive learning mechanisms. Technological innovations could come from a conscious and intentional process, through which R&D co-operative projects are assembled, or could be naturally attained as a sub-product of productive and technological relationships among network members. This propriety assumes great importance in dynamic technological environments, in which the improvement of firms' competitiveness requires a process of continuous introduction of innovations into the market.

Two additional aspects must be considered. The first refers to the necessity of following up the evolution of those proprieties during a time lag, as they refer to an inter-temporal dynamics. The second aspect involves the possibility of identifying trade-offs among those proprieties, which can be reinforced along time due to competitive pressures. It is supposed that the possibility of inter-firm networks generate competitive gains depends on the evolution of industrial contexts. In other words, there is a strong connection between networks evolution and the evolution of competitive patterns in the associated industries. It is possible to define a cast of sector trends related to the importance of co-operative links

for industrial competitiveness, utilising them to evaluate networks' internal proprieties in those contexts. So, networks' efficiency would be correlated to a consistence between its internal proprieties and that trends.

2. Technological Complexity and Institutional Diversity of Inter-Firms Networks

2.1 - Technological Systems and Technological Regimes

Despite its usefulness as an economic concept that captures the increasing importance of co-operative links among firms to the enhancement of industrial competitiveness, it is virtually impossible to define a generic model of inter-firm networks that can be applicable to different industrial contexts. Due to the institutional diversity of these networks, analyses about the phenomenon have usually opted to reduce the focus, through the selection of an analytical cut oriented to particular aspects of them. In contrast with other cuts, we shall develop our analysis based on the specificity of the technologies mobilised at the network level. This approach is particularly based in the idea that the co-evolution of technology and (inter)organisational forms constitutes an important element of industrial dynamics (Nelson, 1994; Dosi and Kogut, 1993; Dosi and Malerba, 1996). Two main hypotheses are implicit in this approach. The first is based on the assumption that the patterns of inter-firm co-operation are technology-specific. The second hypothesis assumes that inter-firm networks should be seen as inter-organisational forms that require a complex integration of productive activities, competencies and knowledge, being based on institutional arrangements that reflect this complexity. On this basis, two objectives of the analysis should be identified. The first involves the definition of objective criteria to map the institutional diversity of inter-firm networks, specifically associated with the 'complexity' of the technological environment in which they're inserted. The second objective involves the identification of 'stylised models' of inter-firm networks with basis in the same criteria.

The enhancing of inter-firm co-operation is strongly conditioned by the characteristics of technologies employed. According to Joly and Mangematin (1995), we can identify two general trends associated with the increase of technological complexity. The first involves the increase of the complexity of production processes in terms of the number of inputs required, which causes an increase in the utilisation of external resources. The second trend involves a sophistication of the knowledge and skills that must be integrated to make production feasible and to generate technological innovations. Considering these trends, we can suppose that the more 'complex' is the technological environment in which the firm is inserted the more critical will be the access to complementary assets and competencies.

The concept of 'technological systems' developed by Carlsson and Stankiewicz (1991) seems particularly useful to characterise the environment in which inter-firm networks are embedded. Lundgreen (1995) associates the concept of technological systems with two important aspects: (i) technological interrelatedness, when the functioning of the parts is contingent upon the functioning of the whole system, creating a kind of 'system's indivisibility'; (ii) network externalities related to situations in which the value of a technology is dependent upon the total numbers of adopters integrated in a system. These aspects can be linked to the discussion of the 'complexity' of technological systems. According to Singh (1997), three characteristics can be associated with the concept of 'technological complexity'. The first involves the 'systemic character' of complex technologies, which means that a complex product or technology comprises different elemental units or components, usually organised in hierarchies of subsystems, in a way

that the performance of the system is strongly dependent on the performance of its subsystems and components. The second characteristic involves 'multiple interactions' among system's components, related to feedback mechanisms in terms of technical performance. The third characteristic is related to the 'non-decomposable' character of complex technologies, which can be found in situations where the product cannot be separated into its components without seriously degrading its capabilities or performance.

However, not only the complexity of the 'technological systems' affects the structure of inter-firm networks. The complexity of the knowledge that has to be mastered to generate technological innovations also performs a decisive role in the creation of incentives or hindrances for co-operative arrangements. In fact, many technological innovations undeniably have been systemic in nature, involving several streams of scientific disciplines and/or different core technology areas, as stressed in the analysis of Baba and Imai (1989) and Rothwell (1992). The consolidation of 'systemic innovations' that require the integration of complementary competencies has induced different forms of technological co-operation between firms. Since these innovations require the integration of different and heterogeneous technologies and expertise, firms usually have to cope with technological disequilibrium and technological bottlenecks.

To discuss the connections between the complexity of relevant knowledge and the emergence of inter-firm networks, the concept of 'technological regime' developed by Nelson and Winter (1982) and Malerba and Orsenigo (1993) seems particularly useful. Among the aspects of 'technological regimes' that affect the possibilities of co-operation between firms, we can stress the importance of characteristics of knowledge base that has to be activated to generate technological innovations. Three dimensions of the knowledge base affect decisively the possibilities of co-operation. The first involves the degree of 'tacitness' of knowledge base. The more the knowledge is tacit (Senker and Faulkner, 1995), the stronger will be the need to develop codes and channels to change information between agents with complementary competencies, and the weaker will be the possibility to transfer it through trivial market relations. Foray and Lundvall (1996) stress the importance of networks to the 'codification' of tacit knowledge, which involves a process of reduction and conversion that render especially easy the transmission, verification, storage and reproduction of knowledge. The second dimension involves characteristics of different kinds (or 'fragments') of knowledge that are relevant in each technological regime. In fact, this knowledge is usually produced through social practices developed in specific communities, whose consolidation can be linked to the emergence and consolidation of social networks. The third dimension involves its degree of 'complexity', which can be related to two aspects: (i) the diversity of scientific disciplines and technologies that must be integrated in order to generate innovations; (ii) the spectrum of different competencies concerning the production process, the nature of markets, the features of demand and so on. In fact, the more the knowledge base is 'complex', the stronger will be the need for individual firms to develop mechanisms to integrate the various fragments of knowledge generated externally, which reinforces the relevance of co-operative links with other agents and the availability of transference mechanisms that make easier this integration. At the same time, the more the knowledge is 'complex', the more difficult will be the 'standardisation' of informational flows and organisational procedures between firms. In these circumstances, the organisational design of co-operative arrangements has to be sufficiently flexible to permit the integration of different actors and their competencies, according to the requirements of the processes of production and innovation.

2.2 - Inter-Firms Networks and Technological Complexity: a Tentative Typology

In the last years, a wide literature has tried to build comprehensive typologies of inter-firm networks. These typologies are based on different analytical cuts, using distinct criteria to map the structures. Despite the problems and caveats that are usually present in the construction of these typologies, they can be used as an auxiliary device, in order to understand some characteristics of these networks. Based on a systematisation effort, some 'stylised models' of inter-firm networks can be identified. In order to capture the heterogeneity of these arrangements, some characteristics of the technologies mobilised at the network level are emphasised. Specifically, two elements are considered as criteria to classify network forms: (i) the complexity of 'technological systems' in which networks are inserted, particularly in terms of the architecture of products generated and of the interconnectedness of productive activities performed; (ii) the complexity of 'technological base', particularly in terms of the diversity of competencies and skills that must be mobilised to generate innovations. According to these criteria, four types of inter-firm networks can be characterised (Figure 2):

Figure 2 – A Typology of Inter-firm networks

		Complexity of Technological Systems	
		low	high
Complexity of Technological Base	high	<p style="text-align: center;">Technology-Structured Networks</p> <ul style="list-style-type: none"> . mass-production products with a modular architecture . large-scale production with a hierarchy of components and sub-systems . competitive gains: products' differentiation and modularity 	<p style="text-align: center;">Complex Technology Networks</p> <ul style="list-style-type: none"> . very complex products based in integration of sub- systems . project-based production (small batches tailored to specific users) . competitive gains: high performance customised solutions
	low	<p style="text-align: center;">Traditional Networks</p> <ul style="list-style-type: none"> . non-complex products associated to traditional sectors . small-scale production and inter-firm specialisation . competitive gains: low cost and productive flexibility 	<p style="text-align: center;">Technology- Based Networks</p> <ul style="list-style-type: none"> . high-tech products associated to emergent markets . development of specific technologies with economic potential . competitive gains: innovative rents generated by new products

(i) **Traditional Networks:** involves non-complex products - which can be produced in small-scale units - and a knowledge base relatively simple. In these networks the number of components and sub-systems that must be integrated is relatively low, being associated to 'non-complex' architectures. Competitive gains are usually associated with the dissemination of a process of 'flexible specialisation' (Piore and Sabel, 1994; Best, 1990) among firms, which results in the decrease of production costs and in the increase of productive flexibility. Interactions between network members involves a non-complex logistics and a limited interchange of information. Innovative efforts are also limited in these arrangements, involving incremental changes in the design of the product, that hardly modify its 'architecture'. Examples of these kind of arrangement have been associated to different industries, such as textile, shoes, furniture, metal craft and food.

(ii) **Technology Structured Networks:** involves products with a sophisticated architecture of components and sub-systems, reflecting a high complexity of the respective 'technological system'. In this case, the large-scale production involves a complex hierarchy of components that have to be integrated at the network level. Nevertheless, these networks are usually associated with a relatively stable knowledge base, reflecting a certain maturity in terms of the life cycle of products, despite a continuous process of differentiation with basis in the principles of modularity. The examples of the automobile industry and other assembly industries (computers, electronic equipment etc.) have been recurrently linked to this kind of arrangement. Competitive gains in these networks involve not only the reduction of costs of components but also the increase of the variability of the range of products generated, due to changes in the components integrated in a 'modular architecture'.

(iii) **Complex-technology Networks:** involves high-cost, engineering intensive capital goods that are produced as one-off items or in tailored batches - usually on a project basis - for individual customers. These networks involve products with a high level of technical complexity - which demands the integration of different technologies - and that require the integration of different knowledge bases. Examples of this kind of product are: air-traffic control systems, aircraft engines, banking automation systems, flight simulators, flexible intelligent buildings, automatic manufacturing systems, mainframe computers, nuclear power plants, offshore platforms, robotics equipment and satellite systems. The dynamic of innovation in these networks is strongly based in complex interfaces between components and sub-systems and in the active involvement of users. Competitive gains generated are usually related to high performance customised solutions, attending specific demands of sophisticated buyers.

(iii) **Technology-Based Networks:** involves the generation of new technologies - in terms of their life cycle - with a complex knowledge base that requires large investments in R&D. However, the complexity of productive activities in these networks is relatively low, because these arrangements do not involve sophisticated hierarchies of components and sub-systems. The critical activities to network logistics are performed by 'technology-based firms' specialised in specific fields of knowledge, which perform a central role in the innovative process. These arrangements are tailored to permit the integration of complementary competencies with the aim of developing specific technologies with an attractive economic potential. Examples of high-tech industries such as biotechnology, opto-electronics, new materials and semiconductors have been recurrently related to this kind of arrangement.

3. - Characteristics and Determinants of Competitiveness in Stylised Models of Inter-Firm Networks

3.1 - Traditional Networks

These networks can be related to the consolidation of contractual relations between assemblers and suppliers in traditional industries, being based on the principles of 'flexible specialisation' (Piore and Sabel, 1984; Best, 1990). The functional specialisation of suppliers in different stages of the production cycle is the main characteristic of this kind of arrangement. They are often associated with processes of vertical disintegration of firms located in specific points of the productive chain, which tend to induce the strengthening of interactions with suppliers. From a spatial point of view, these networks are usually

associated with the traditional concept of 'industrial districts' (Marshall, 1920), which emphasises the potential benefits of a productive specialisation between firms located in the same geographical region. In a broader sense, these networks can be characterised by the low technical complexity of products generated (which can be produced in small-scale units) and by the simplicity of the knowledge base that has to be mastered to obtain a product accepted by the market.

Products generated have usually low value, low volume and a simple design. These products are usually related to industries that do not deal with complex technologies, in which the main front of technical progress comes from outside, involving the supply of equipment and other inputs. The products generated can also be related to high tolerance margins in terms of productive procedures and quality level. These products involve a limited number of components, being based in relatively simple 'architectures'. The 'division of work' inside these networks are usually based on the generation of economies of specialisation in the production of inputs, parts and components, in order to reduce production costs and to facilitate adaptations in face of a volatile demand. The provision of technical services at the local level - seen as positive externalities that increase productive efficiency - tends also to be developed as a consequence of co-operative links between network members. We can also mention the generation of scope economies and productive flexibility at the level of assembly firms, due to the intensification of their interactions with a net of specialised suppliers.

Despite the possibility of other gains, the reduction of production costs tends to perform a critical role in the establishment of those networks, being the most important propriety of them. The relevance of reinforcing productivity gains is often explained by the increase of competitive pressures. In terms of productive logistics, these networks do not involve specific mechanisms oriented to the optimisation of internal flows. Despite the generation of scope economies at the level of assembly firms, the management of internal logistics at the network level does not involve just-in-time practices or other sophisticated inter-organisational techniques. In fact, the internal logistic of these networks could be seem as an evolution of the traditional 'putting out' system, involving interactions mediated by pre-definition of orders that might be attended by suppliers. As a general tendency, the logistic of transaction flows between assembler firms, dealers, retailers and distributors tends to be more relevant than the flows connecting these agents with a net of suppliers.

The inter-organisational basis of these networks reflects the characteristics of the process of 'flexible specialisation'. They typically involve relations between semi-verticalized assemblers of non-complex products (shoes, textiles, etc.) and a network of firms responsible by the production of inputs, components, parts or by specific tasks in the productive chain. The possibility of separating the different technical tasks - due to the simplicity of product architecture - make easier the establishment of systematic relationships between network members. Sometimes, the emergence of these networks has been related not only to strictly economic factors but also to specific conditions of the socio-economic environment around them. The embeddedness of these networks in localities with a favourable industrial atmosphere generates many benefits - such as the exchange of ideas, information, resources and goods and also the accumulation of skills and capabilities - making easier the generation of technical gains and the adoption of collective actions that increase the productive efficiency. The governance structure is usually dispersed, presenting a low level of hierarchisation and being based on a functional specialisation of independent agents. They can be characterised as polycentric

networks, in which the actors co-operate or compete with each other on a voluntary basis, through a set of vertical and horizontal relations.

The process of inter-organisational co-ordination can be associated with some specific properties of these networks. The process of collective co-ordination involves two main alternatives. The first is based on a co-ordination promoted by external agents (dealers) through the definition of new designs that must be attended by suppliers. The second would be based on a co-ordination promoted by assembly firms at the end of productive chains, through the definition of orders. However, the two alternatives are usually based on short-term contracts that hardly include incentive mechanisms oriented to the generation of technical-productive gains on the orbit of the supply chain. On the other hand, the structural flexibility seems to be an important propriety of these networks. The contractual rules that orient sub-contracting relations are usually based on sequential spot contracts periodically revised, making easier the replacement of suppliers and, simultaneously, reducing turnover costs to the buyer and increasing its operational flexibility. Thus, the structure of the network could increase or decrease according to the seasonal evolution of demand. Nevertheless, adaptations in face of market changes can often be traumatic to suppliers which have to face a suddenly reduction of orders. Due to the limited bargain power of suppliers, eventual conflicts with dominant buyers tend to be resolved through a 'exit' mechanism, instead of through 'voice' mechanisms (Helper, 1993) based on negotiations and mutual commitments between the parts.

The informational connections between firms tend to be less sophisticated than those associated with other forms of inter-firm networks. Specifically, informational flows involve a non-systematic interchange of information about performance and quality of components. Informational flows usually assume a one-way direction in these networks, coming from dealers and assembly firms in the direction of a diverse net of suppliers. These flows involve the previous definition of design and others products' attributes that must be attended by suppliers. Due to the simplicity of informational flows, they hardly require the creation of a dedicate infrastructure and the definition of specific protocols. Despite that, the volatility of market tendencies often impose the need for an efficient communication between assemblers (or dealers) and suppliers, in order to adapt some attributes of the components produced. Learning mechanisms also assume a specific character in these networks. First, they induce a strengthening of suppliers' competencies, facilitating the upgrading of products' and components' design. Second, they facilitate the diffusion of more sophisticated technical standards, reducing the asymmetries between suppliers in terms of productive efficiency. The diffusion of more rigid quality control procedures can also be attained through these interactions, as well as the dissemination of modern organisational techniques which increase the productivity along the supply chain. Finally, interactive mechanisms assume an important role in the co-ordination of 'collective actions' of network members, reinforcing the mutual commitments between them. On the other hand, the 'non-complex' character of products generated affect the intensity and the orientation of innovative efforts performed at the network level. In fact, innovative efforts assume a non-systematic character, involving incremental innovations based in learning mechanisms that emerge as a sub-product of productive practices.

The process of technological co-operation can be associated with some specific properties of these networks. The informational density tends to be relatively limited in these networks, with informational connections involving a non-systematic interchange of information about performance and quality of components. Due to the simplicity of informational flows, they hardly require the creation of a dedicate infrastructure and the

definition of specific protocols. Despite that, the volatility of market tendencies often impose the need for an efficient communication between assemblers (or dealers) and suppliers, in order to adapt some attributes of the components produced according to those tendencies. The importance of these networks to reinforce innovative strengths is also limited. In fact, the 'non-complex' character of products generated affects the intensity and orientation of innovative efforts performed at the network level. We can also observe some interactive learning mechanisms that perform an important role at the network level. The diffusion of more rigid quality control procedures and more sophisticated technical standards can be obtained through these interactions, as well as the dissemination of modern organisational techniques that increase the productivity along the supply chain.

3.2 - Technology Structured Networks

These networks involve a variety of actors that interact in productive chains related to mass-production environments. The main actors of these networks are large assembly firms, suppliers of sub-systems to be integrated in the final product (that are usually also large firms), suppliers of components and raw materials. Competitive gains associated with these networks involve not only the reduction of costs of components but also the increase of the variability of the range of products due to changes in the components integrated in a 'modular architecture'. As a consequence, relations between suppliers and assemblers are formatted to induce productive and technological co-operation. Examples of this kind of arrangement have been associated with changes that can be observed in the automobile industry and other assembly industries (computers, electronic equipment etc. Products generated through these networks have high value, high volume, high variety and technical complexity. They usually involve a complex design, based on a diversity of components and sub-systems integrated through linear-linked mechanisms. The technical sophistication of products and components results in low tolerance margins to the activities performed in productive chains. The integration of components is usually based on 'modular architectures' that permit different combinations of them in similar platforms, generating a large variety of products and attending the principles of 'mass customisation' (Pine, Victor and Boynton, 1993). The concept of mass customisation involves the production of varied and often individually customised products at the low cost of standardised, mass produced goods. Mass customisation could be seen as a more advanced stage of a continuous improvement process, linked to an architecture based on different modules, which can be rapidly integrated in the best combination or sequence required to tailor products.

The increase of technical gains in these networks can be associated with the simultaneously generation of economies of scale and scope. According to Noori (1990), the concept of 'economies of integration' could be related to synergies whose dependence relies on the co-existence of scale and scope economies. To obtain these gains, a focus restricted on the reduction of production costs through the specialisation of suppliers seems not to be sufficient, demanding a focus on total value chain improvement, as well as substantial investments in productive co-ordination mechanisms and dedicated assets. Three aspects are particularly important to achieve these gains: (1) a sophisticated level of automation which allows for operation of CIM (computer-integrated manufacturing) systems; (2) technological developments in product design, based on the increase of modularity of components; (3) the sophistication of the manufacturing of sub-assemblies and parts. On the other hand, the strengthening of productive logistics in these networks could be associated with an optimisation of the transactional links between assemblers and suppliers, strongly based on the dissemination of just-in-time practices in inter-firm

relations. The increase of reactivity in face of market changes is an important aspect of competitive gains obtained in these networks, being based on a productive flexibility related to the diffusion of just-in-time practices and to the generation of a wide range of products with basis in the principles of modularity. This point is emphasised by Coriat (1995) in a characterisation of 'regimes of variety', seen as flexible mass production systems. The implementation of total quality control systems between assembler and suppliers is also a pre-requisite for the consolidation of this kind of regime, involving certification practices carried out in accord with specific protocols that try to construct new routines in the relationships between assembler and suppliers.

The *governance* structure of this kind of network is based on the central role performed by a core assembler positioned in the apex of the network. It is also very common a hierarchisation of suppliers of sub-systems and components in different levels - first-tiered suppliers, second-tiered suppliers, etc. - according to their technical expertise and to the intensity of their interaction with the core assembler. When the process of exchange between suppliers and assembler gains a multidimensional dimension, the responses to inter-firm problems tend to become based on mechanisms of negotiation, oriented to a long-term logic of co-operation. We can also observe a tendency to a spatial agglomeration of assembler and suppliers, in order to facilitate the co-ordination of productive activities in the supply chain. The interactive character of network relations comprises multidimensional mechanisms of co-ordination, involving, among other aspects, the quality of the component produced, the adoption of just-in-time practices in the delivery logistics and the continuous incorporation of technological innovations. In terms of the contractual basis, the mechanisms of co-ordination are strongly based on long-term contracts with specific incentive mechanisms to stimulate the increase of productivity and quality of components. Not only there is a dissemination of long-term contracts in this kind of arrangement, but also a general expectation that business relationships will go beyond those contracts. Along time, the development of a mutual trust among buyer and suppliers tends to be reinforced as a sub-product of co-operative practices.

The process of inter-organisational co-ordination can be associated with some specific properties of these networks. The mechanisms mobilised to co-ordinate the actions of firms (assembler and suppliers) are also very complex. At the productive orbit, these mechanisms involve sophisticated methods of production planning and a widespread use of protocols based on just-in-time principles (Coriat, 1995). The mechanisms of co-ordination also involve specific projects oriented to the co-development of new components and sub-systems between assembler and suppliers, as well as the management of the modular architecture to generate a large variety of products. The mechanisms of co-ordination tend also to vary according to the position of suppliers in different levels of the network. In fact, the closer to the core assembler they are in the governance structure, the more intense and multidimensional will be the process of co-ordination. The structural flexibility tends to be relatively limited in these networks, due to the stability of inter-firm relations, seemed as a pre-requisite to the intensification of co-operative practices between network members. The consolidation of a bilateral dependency between suppliers and buyers makes more difficult the replacement of agents, creating exit barriers. In this sense, the notion of 'flexibility' can be associated with co-operative practices that permit to co-ordinate the adaptations required in face of market changes, making them less traumatic to the firms involved. As a consequence, assembler's response to problems with suppliers is usually based on mechanisms of negotiation, oriented to a long-term logic of co-operation. Eventual problems tend to be

resolved through a 'voice' mechanism, involving the deepening of interactions until the problem is corrected.

In terms of technological co-operation, these networks can be related to sophisticated informational flows. Specifically, informational feedback from suppliers tend to be encouraged. Some aspects of this process might be emphasised. First, we can mention a continuous interchange of information about performance and quality of components and sub-systems between assemblers and suppliers. This interchange can be related to the consolidation of specific learning mechanisms that facilitate the improvement of existing products and the generation of new models based in adjustments in the modular architecture. The co-development of new components and sub-systems also results in an intensification of informational flows between assemblers and suppliers. Informational flows assume a two-way character, making use of a sophisticated informational infrastructure (EDI dedicated systems, for example) and being associated with the development of specific codes of communication. Innovative efforts in these networks usually involve 'programmed innovations', through product development projects based on the integration of new components and sub-systems in a modular architecture. As a general tendency, the design and development of products have been devolved back in the supply chain (Roy and Potter, 1996). We can observe a mixed situation, where the design of some sub-assemblies and components are devolved to suppliers and where designers of assembler firms work closely with their suppliers to ensure that components with the required performance and quality are developed. The level of interaction between assemblers and suppliers also varies greatly along the supply chain. Specifically, we can observe strong interactions with 'first level' suppliers to develop new components. Situations in which assemblers pre-select specific suppliers to collaborate on design and development are also very common. In those circumstances, a kind of joint-development of components can be observed, with intense interchange of information and competencies.

The process of technological co-operation can be associated with some specific properties of these networks. Specifically, the improvement of informational density is one of the main characteristics of these networks. In fact, the consolidation of them can be associated with a sophisticated contend of informational flows between assemblers and suppliers. The informational flows involve not only the transmission of orders between assemblers and suppliers, but also several other aspects, such as: (1) development of the specifications related to components and sub-systems; (2) negotiation of delivery logistic; (3) control of the quality of the components produced; (4) solution of technical problems after the order; (5) interchange of technical information. The increase of innovative strengths in these networks can be related to 'programmed innovations' that try to integrate new components and sub-systems in a modular architecture. Four 'outcomes' of innovative efforts can be mentioned. The first involves the continuous improvement of existing components, through traditional forms of learning by using based on interactions among assembler and suppliers. The second impact involves the development of new components and sub-systems to be accommodated in the existent architecture. In fact, the modular character of this architecture generates a kind of 'openness' to new technical solutions that permits an increase of the efficiency of the system as a whole. The third kind of impact involves the development of new variations of products with basis in the same architecture. Through systematic interactions with its suppliers, the core assembler can have access to more sophisticated components that permit an upgrading in terms of the level of product's differentiation. Finally, the fourth impact involves periodic re-definitions and adaptations of

the architecture itself. These improvements are usually linked to an increase of the 'modularity' of the architecture.

3.3 - Complex-technology Networks

These networks involve productive relationships associated with the generation of single-customised 'complex products' through a process of systems integration. They are usually organised in a temporary project basis, involving a diversity of agents and institutions and being oriented to the production of high-cost, engineering intensive capital goods produced as one-off items or in tailored batches for individual customers (Hobday, 1997). The products generated present a high level of technical complexity, demanding the integration of different sub-systems and a integration of hardware and software. They are also extremely engineering intensive, involving a diversity of technical skills and complex interfaces between a hierarchy of sub-systems. The 'complexity' of products involves the integration of semi-autonomous sub-systems, sometimes based on very different technologies. Due to the diversity of sub-systems that must be integrated at the product level, these networks are usually associated with non-linear proprieties of architectures, with several points in which relevant innovations can be incorporated. Products generated also involve very low tolerance margins because they have to satisfy very demanding customers in terms of technical performance. Among the examples of this kind of product described in the literature, we can mention air-traffic control systems, aircraft engines, flight simulators, flexible intelligent buildings, manufacturing systems, mainframe computers, nuclear power plants, offshore platforms, robotics equipment and satellite systems. These networks are created with the objective of generating customised products that attend specific demands in terms of performance, capacity and reliability. Competitive gains are usually associated with high performance customised solutions that attend specific demands of sophisticated buyers.

Compared with other kinds of networks, the generation of technical gains associated with scale or scope economies is less important. In fact, competitive gains generated by these networks are usually based on high performance customised solutions that attend specific demands of sophisticated buyers. Among the technical-productive gains obtained, we can mention: (i) specialisation gains in the production of sub-systems, due to the specialisation of suppliers; (ii) increase of functional performance of products generated, through the integration of hardware and software; (iii) customisation gains based on a technical co-ordination promoted by 'systems integrators'. As a general tendency, the increase of the functional performance of the products generated, to attend sophisticated buyers, is much more important than the reduction of production costs. The productivity and efficiency of this kind of production are strongly linked to a experience in the management of complex projects, being based on the integration of multiple competencies and in horizontal interactions that permit a continual readjustment and redefinition of tasks. On the other hand, the optimisation of productive logistics assumes a specific character in this kind of arrangement. The improvement of this logistics involves the dissemination of parallel engineering and others techniques that permit the management of complex projects. The management of these projects requires a capacity to integrate multiple competencies and to organise horizontal interactions between very different actors, in order to permit the readjustment and redefinition of tasks. To make these adjustments, the deepening of productive and technological co-operation between 'systems integrators' and an extensive network of suppliers of components and sub-systems seems to be indispensable. In these circumstances, the improvement of productive flexibility is directly linked to the competencies of the agents who act as 'system integrators'.

The 'complexity' of products tends to be reflected in the 'institutional' form of these networks. In fact, we can identify a diversity of actors that must be mobilised to make the production feasible. The main actors are firms that act as 'systems integrators', responsible for the integration of multiple competencies and for the co-ordination of the internal flows (tangible and intangible) of the network. The presence of a temporary network of suppliers of sub-systems, components and software is also an important characteristic of the arrangement. As the final aim of the network is to attend demands of sophisticated buyers, they also perform an important role in the network. We can also mention two other actors that, according to the circumstances, perform an important role in these networks. First, we can identify the presence of engineering firms that sometimes act not only in the co-ordination of specific phases of the process, but also as 'systems integrators' themselves. Second, there are government regulators that, in some circumstances, influence the management of projects, affecting important aspects of network *modus-operandi*. The typical relations in these networks involve firms that act as 'systems integrators' and a network of suppliers of sub-systems. The 'governance structure' is relatively 'fluid', being based on specific projects with a transitory character, in which we can observe a previous definition of tasks to be performed by network members. Contrasting to others networks, the 'governance structure' tends also to be more 'concentric', with the suppliers of sub-systems directly linked to 'systems integrators'. We can also observe a lot of horizontal interactions between technologies used in different points of the network.

The process of inter-organizational co-ordination can be associated with some specific properties of these networks. Due to the 'complexity' of products, an efficient co-ordination of transactions performs a critical role. The co-ordination of internal flows is the main function of 'systems integrators', being based on an '*ex-ante*' co-ordination associated with project management techniques. The process of co-ordination usually involves few large transactions between 'systems integrators' and a net of sub-systems suppliers. These transactions tend to be based on incomplete contracts, involving negotiated prices that often act as 'incentive mechanisms' to the increase of productivity. In the process of co-ordination, an intense use of information technologies and customised software can be observed, as well as techniques of 'parallel engineering' that increase the performance of the network as a whole. Contrasting with others networks, the importance of co-ordination processes goes beyond the improvement of the technical performance, involving the establishment of productive and technological links that progressively induce the consolidation of a 'new' market, specifically related to the 'complex product' generated. In this sense, non-market mechanisms play an important role in the co-ordination of economic activities, which is based on inter-firm *ex-ante* co-operation, agreement and negotiation of technical issues related to the stages of design, development and manufacture. The characteristics of inter-firm relations in these networks also affect the possibilities of improving their structural flexibility. Relations are usually based on specific projects, in which we can observe a previous definition of tasks to be performed by network members. Despite the transitory character of the projects, firms inserted in these networks are supposed to establish systematic relationships among themselves in order to permit the mobilisation of resources as soon as it seems necessary. Specifically, these networks could be seen as 'virtual' task-forces that could be activated by systems integrators in order to develop new projects or to correct some aspect of projects already finished, due to specific demands of the buyers. These arrangements involve the consolidation of temporary alliances for innovation and production, conforming a kind of 'virtual' network that could be mobilised to implement new projects.

The characteristics of innovative efforts performed at the network level differentiate 'complex products networks' from others arrangements previously mentioned. In fact, in these environments the dynamics of innovation is extremely different from other types of networks, especially those that involve mass products based on standardised components. According to Hobday (1995 and 1997), this dynamics is strongly based on complex interfaces between components and sub-systems and on an active involvement of users. Basically, innovative efforts present a project-basis character oriented to systems integration. There are many 'points' in these systems where innovations can be incorporated; however, more than punctual innovations, this logic involves making compatible the technical attributes related to different components. The complexity of the projects developed through the co-ordination of 'systems integrators' makes extremely important the capacity of mobilising disperse pool of competencies and skill, in order to generate the technical solutions required by sophisticated buyers.

The process of technological co-operation can be associated with some specific properties of these networks. The informational density is a characteristic particularly important in these networks. In fact, the 'complex' character of products generated requires an intensification of informational flows between network members, in order to permit an integration of multiple competencies and skills. Some characteristics of those flows may be pointed out. First, we can observe an intense involvement with the users of these products in order to define their needs and to customise the system. This involvement should start in early stages of the definition of the project, being maintained and deepened in the next stages. Second, we can mention the intense interchange of information about sub-system proprieties that must be integrated at the project level, which induces many horizontal links between 'systems integrators' and the net of suppliers. Third, there are informational flows with a two-way character specifically associated with project management techniques. Finally, we can mention informational flows related to a sophisticated technical assistance developed between users and 'systems integrators', associated not only with adaptations that permit an increase of products' performance (but also with an eventual replacement of the product by a new model, based on new projects. The reinforcement of innovative strengths is one of the main determinants of the competitiveness of these networks. Due to the diversity of sub-systems that must be integrated at the product level, these networks are usually associated with non-linear proprieties of architectures, having several points in which relevant innovations can be incorporated. As a result of the non-linear proprieties of inter-dependent sub-systems, innovative dynamics tends to involve not only changes in the components and technologies used, but also the ways components and sub-systems are configured to form the architecture of the product. In this sense, the integration of hardware and software to attend the specific needs of users becomes an important element of innovative dynamics. We can also emphasise two others aspects of innovative efforts in these networks. First, innovative efforts require a strong user-producer involvement, in a way completely different from the more 'informal' paths of interaction between users and producers that prevail in other networks. Second, due to the technical interconnections and interdependencies between different sub-systems, the innovation paths tend to be agreed *ex-ante*, in order to avoid problems that could jeopardise the performance of the system as a whole.

3.4 - Technology-Based Networks

These networks are specifically related to products based on new technologies in terms of their life cycle, involving the integration of complex knowledge and requiring large

investments in R&D. Relationships inside these networks are associated with the integration of complementary assets and skills, involving knowledge that come from different scientific spheres. Nevertheless, the technical complexity of the production is relatively low in the sense that we can not identify a very complex structure of components and sub-systems to be technically integrated in order to generate a specific product. Critical activities in productive chain are usually performed by 'high-technology firms', specialised in specific fields of knowledge. Examples of high-tech industries, such as biotechnology, opto-eletronics, new materials, semiconductors and software have been recurrently associated to this kind of arrangement. From a spatial point of view, these networks can often be seen as a variation of 'industrial districts', specifically oriented to high-tech industries, being based in the built of 'technological poles' or 'technological parks'. Sometimes, the creation of a market for these products can be seen as a result of links that emerge with the consolidation of the network. The 'emergent' character of the markets has two main implications. First, the consolidation of the market could be related to a long development cycle, through which we can observe the intensification of productive and technological links between different agents integrated in the network. Second, as a consequence of the 'emergent' character of the markets, the proprieties of the product tend to be defined with basis in mutual interactions and learning mechanisms between producers, suppliers and customers.

These networks are based on co-operative relationships between firms with complementary competencies, in order to accelerate the introduction of technological innovations into the market. They usually involve two main aspects: (i) the establishment of close connections between R&D activities and industrial production, often based in subcontracting relations; (ii) the establishment of a division of work in terms of the stages of a R&D cycle, often characterised by feedback loops (Kline, 1986). In this sense, two main objectives can be related to the consolidation of this kind of arrangement. First, we can stress the integration of competencies in different stages of the cycle R&D-production, reducing the lead-time associated to the development of new technologies. Specifically, these networks facilitate the process of technology transfer between high-tech firms and end-users sectors. Second, these networks perform an important role in terms of the 'construction' of markets, allowing the establishment of links that could progressively induce the consolidation of productive chains in high-tech industries.

These networks can be related to different technical gains. However, these gains are not directly related to the reduction of costs and to the increase of productivity in the productive orbit but to the reduction of lead-time associated with the transition R&D-production. The efficiency of R&D process increases because of the interchange of information between network members specialised in the different stages of the process. There are some external economies in the provision of technological services that can be obtained due to the consolidation of the network. The provision of these services requires the previous existence of a demand, which is often limited at the level of isolated firms, growing with the establishment of systematic links between firms integrated in a network. Specialisation gains associated with techno-scientific core competencies can be obtained at the network level, reinforcing the 'productivity' of activities in which the control over intangible assets performs an important role as determinant of industrial competitiveness. The incorporation of innovations generated at the network level increases the technological sophistication of products of end-users sectors reinforcing the competitiveness of those firms. On the other hand, the optimisation of productive logistics does not be an important task of these kind of network because the critical competencies mobilised at the network level are related to pre-competitive activities.

The main actors present in these networks are 'technology-based firms' (*spin-offs*), potential users of the technologies generated, suppliers of components, equipment and services, research institutes and universities. Relationships established between firms involve a division of tasks in the cycle R&D-production. Specifically, we can observe a convergence of network internal flows in the direction of technology-based firms, which perform a central role in the innovative process. Nevertheless, these firms are usually dependent of complementary resources and assets retained by others agents inserted in the network. The *governance* structure of these networks is based on a more fluid definition of tasks, according to requirements related to the integration of different stages of R&D process. Despite the heterogeneity of governance structures, we can mention the central role of technology-based firms in the co-ordination of internal flows of the arrangement. Specifically, three alternatives in terms of governance structures might be mentioned. The first involves situations in which the 'user-sector' of the technology induces the consolidation of the network, establishing co-operative links with technology-based firms that would be responsible for the development of specific technologies. The second alternative contemplates situations in which technology-based firms act as leaders of the network, co-ordinating a division of work with other firms inserted in the arrangement, through which the integration of complementary competencies can be attained. The third alternative involves the consolidation of 'compact' networks, based on the previous existence of a 'social milieu' (Maillat, Crevoisier and Lecoq, 1994) that creates an opportunity to innovate for the various partners, based on an unstable division of work and on diffuse rules connected with a feeling of belonging to a community..

The process of inter-organisational co-ordination can be associated with some specific properties of these networks. The forms of co-ordination vary according to the stage of network consolidation. In the early phase of this process, the realisation of R&D projects co-ordinated by technology-based firms seems particularly relevant. There is also a possibility of a broader co-ordination through co-operative programmes with a public or semi-public character. The impossibility of defining the 'outcome' of these projects in a strict manner results in the use of 'incomplete contracts' as a tool to define the rules of interactions between firms. Among the different aspects of these contracts, particular importance is generally attributed to the pre-definition of appropriability conditions of the innovations generated. We can also observe adaptations in terms of the 'governance' structure of these networks according to an evolution of the 'life cycle' of technologies and products generated. Along the different stages of this cycle, the level of 'centralisation' of the structure tends to increase, with the arrangement progressively changing from structures that can be strictly characterised as 'research networks' to structures closer to the general model of 'industrial networks'. In this sense, we can mention the inter-penetration of ownership rights between technology-based firms and large companies located in the end-user sectors of technologies generated, which act as incentive mechanisms to sustaining some forms of co-operation. In terms of their "structural flexibility" we can observe that these networks tend to be relatively 'volatile' because situations in which the innovative process demands important changes in network structure - through the acquisition of technology-based firms by large companies, for example - are very common. However, compared with other kind of networks, we can also note that these changes are not primarily related to market stimulus but to endogenous forces related to exigencies of the R&D cycle.

Technological co-operation in these networks is strongly related to the integration of competencies and to interactive learning that permit the increase of the efficacy of R&D

process. Among the aspects that can be related to the increase of efficacy of innovative efforts, the following could be mentioned: (i) the establishment of a 'division of work' in terms of innovative efforts, based on a technological specialisation of network firms; (ii) the establishment of closer connections between technology-based firms and end-user firms, which could be related to 'learning-by-using' mechanisms; (iii) the integration of technological and scientific competencies that present a complementary character. Innovative efforts in these networks are strongly related to different stages of R&D cycle, being based in a 'division of work' between firms specialised in these stages. Despite the difficulty to identify *ex-ante* the results of R&D projects, they usually involve relatively well defined technologies that are supposed to perform a relevant function in some industrial activities, associated with end-user sectors to which the network is connected. In this sense, we can associate network flows with an organisation of R&D activities based on the principles of the 'chain linked model' developed by Kline (1986). The deepening of 'learning-by-interacting' mechanisms between network members has also two important consequences. First, it facilitates the definition of 'appropriability conditions' to the innovations generated, which could be obtained through negotiations between parts that establish systematic channels of communication among themselves. Second, it facilitates the definition of language codes between different cognitive backgrounds, helping the interchange of information and the integration of complementary competencies.

The process of technological co-operation can be associated with some specific properties of these networks. The informational density tends to be particularly strong in these networks involving feed-back loops between different R&D stages. Informational flows are usually very complex, being based on inter-personal and inter-teams relations, through which a transmission of tacit knowledge can be obtained. In fact, the network performs an important role as a structure that induces a 'codification' of a knowledge which comes from very different cognitive backgrounds and from different techno-scientific fields. In this sense, the presence of 'bridge institutions' connecting actors with different cognitive backgrounds (technology-based firms, industrial firms of end-user sectors, universities, research institutes etc.) seems particularly useful to the consolidation of these networks. The improvement of innovative strengths through the integration and co-ordination of technological efforts performed by network members is also a critical aspect of these networks. The 'division of work' associated to R&D activities generally includes specific efforts in the area of basic research, through which new relevant knowledge can be obtained. R&D process in these networks assumes an interdisciplinary character, involving not only a division of tasks between industrial firms but also strong interconnections with the technological and scientific infra-structure. Network processes could be related to the presence of feed-back loops among different stages of R&D process, including the end-user sector that would incorporate the technologies in their products.

4. Conclusion: some analytical unfoldings

A systematisation of the determinants of competitiveness in stylised models of industrial networks is presented in Table 2. Two observations must be stressed. The first refers to the fact that this systematisation is based on the relative importance of each element in the different models of industrial networks considered. In fact, the importance of these elements can vary a lot in empirical situations, according to competitive pressures in each industrial context. In this sense, the systematisation constructed should be seen as an attempt to identify general trends associated with inter-firm relations, requiring specific qualifications when applied in cross-sector investigations. The second observation is related to changes in the relative importance of those properties over time, due to

disruptive technological innovations or to an abrupt change in competitive conditions. To capture these changes in empirical investigations, a cross-time analysis seems to be indispensable.

Table 2 - Networks Proprieties and Stylised Models of Inter-Firm Networks

	1) Technical Efficiency	2) Productive Logistics	3) Collective Co-ordination	4) Structural Flexibility	5) Informational Density	6) Innovative Strengths
I - Traditional Networks	+++	+	++	+++	+	+
II - Technology Structured Networks	++	+++	++	+	+++	++
III - Complex Technology Networks	+	++	+++	++	+++	+++
IV - Technology Based Networks	+	+	+++	++	+++	+++

symbols: +++ very important; ++ important; + not much important

Some investigation lines to be deepened in subsequent steps of analysis can also be identified. The first refers to the possibility of correlating the structure and characteristics of inter-firm networks ' to the evolution of the technological environment in which those structures are inserted. In fact, the possibility of these networks generate competitive gains to their members depends on the evolution of technologies that define the 'best practices' in each industrial context. In other words, there is a strong connection between network evolution and the evolution of the technological dynamic in the associated industries. Thus, the increase of the 'complexity' associated with the technological environment can likely result in relevant changes in the manner how inter-firm relations are organised. To capture these changes, the deepening of empirical studies seems to be an important task.

The second line of investigation involves the search of some measures of performance that could be correlated to the 'internal proprieties' of industrial networks previously mentioned. In this sense, the development of a 'cross-time' analysis seems particularly useful, involving the identification of changes in network characteristics generated by the intensification of competitive pressures. Specifically, the consistency between the 'internal proprieties' of the networks and the evolution of competitive patterns of the industries in which they are inserted might be evaluated, with basis in some empirical examples of 'stylised forms' previously mentioned. The analysis of these experiences could involve the following steps: (i) a morphological characterisation of the arrangement; (ii) the identification of networks' internal proprieties, which affect their answering capacity in face of environmental stimuli; (iii) the utilisation of sector competition pattern as a reference table to identify the relevance of each one of the internal proprieties while source of competitive advantage to network members; (iv) the evaluation of the impacts in terms of industrial competitiveness, comparing the indicators associated with networks' internal

proprieties with the relevance attributed to them by the competition pattern of the sector - both in the present situation and in the future.

Another line of investigation involves connections between industrial networks and Industrial Policy. Specifically, we can stress the relevance of industrial networks as an analytical cut that can be used to identify policy actions well adapted to the institutional diversity of those arrangements and to their relevance in the reinforcement of industrial competitiveness. In that sense, the impacts of Industrial Policy measures could be discussed with basis in the internal proprieties of industrial networks previously mentioned. Specifically, policy actions might be able to identify what proprieties should be encouraged, in a way to answer more promptly to environmental stimuli. Simultaneously, Industrial Policy should also be able to ensue the evolution of these arrangements over time, identifying their vulnerabilities that need to be eliminated to reinforce industrial competitiveness.

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