Electronic Working Papers Series

Paper No 4

Technological Diversity and Industrial Networks: An Analysis of the *Modus Operandi* of Co-operative Arrangements

Jorge Britto

Science Policy Research Unit
Mantell Building
University of Sussex
Falmer, Brighton
BN1 9RF, UK

Tel: +44 (0) 1273 686758
Fax: +44 (0) 1273 685865
Email: M.E.Winder@sussex.ac.uk
http://www.sussex.ac.uk/spru/

TECHNOLOGICAL DIVERSITY AND INDUSTRIAL NETWORKS: AN ANALYSIS OF THE *MODUS OPERANDI* OF CO-OPERATIVE ARRANGEMENTS

Jorge Britto
Fluminense Federal University (Rio de Janeiro - Brazil)
Visiting Student - TAGS Program - SPRU -Sussex

Abstract

The article discusses the institutional diversity of industrial networks, associating this diversity with the 'complexity' of the technological environment in which these networks are inserted. The analysis is organized in three stages. The first involves the definition of an objective criteria to map the institutional diversity of industrial networks, specifically associated with the 'complexity' of the technological environment in which they are inserted. The second involves the characterisation of 'stylised models' of industrial networks with basis in the criteria previously defined. Specifically, four kind of industrial networks are identified: traditional sub-contracting networks, modular assembly networks, complex products networks and technology-based networks. The third stage involves a characterisation of network *modus operandi* in 'stylised models' of structures, with basis in an analytical framework that correlates the impacts of inter-firm co-operation to three elements: (i) the increase of technical-productive efficiency; (ii) the strengthening of inter-organisational co-ordination to face environmental uncertainty; (iii) the increase of dynamic efficiency through the generation of technological innovations.

TECHNOLOGICAL DIVERSITY AND INDUSTRIAL NETWORKS: AN ANALYSIS OF THE *MODUS OPERANDI* OF CO-OPERATIVE ARRANGEMENTS

1 - Introduction

The recent literature about Industrial Economics has recurrently discussed the characteristics of inter-organisational configurations adequate to face the instability and complexity inherent to 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 which allow a better facing of environmental turbulence. 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' (Gabher, 1993; Hakasson, 1989; Axelsson and Easton, 1992; Karlsson and Westin, 1994). Industrial networks can be conceived as institutionally structured arrangements which enable an efficient organisation of economic activities, through the co-ordination of systematic links that are established among firms inserted in productive chains. They have been analysed as an (inter)organisational form suitable for the built of flexible systems of production, characterised by productive co-operation practices among specialised agents. These analyses emphasise the consolidation of a new 'division of work' among buyers and suppliers, designed to improve production logistic and to guarantee and increase of productive efficiency.

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 industrial networks that can be applicable to different industrial contexts. Due to the institutional diversity of these networks, analysis about the phenomenon have usually opted to reduce the focus, through the selection of an analytical cut specifically oriented to particular aspects of them. In contrast, we shall develop our analysis based on two aspects of these networks: (i) the sectorial diversity of these arrangements; (ii) the specificity of the technologies mobilised at the network level and of the knowledge base associated to them. 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). Our analysis suggests that industrial networks should not be understood as generic inter-organisational arrangements, but as institutional forms conditioned by the specific characteristics of the industries into which they are inserted and by the complexity of technologies that have to be mobilised in these environments.

Three main hypothesis are implicit in the analysis to be developed. The first is based in the assumption that patterns of inter-firm co-operation are sector-specific and technology-specific. We shall discuss how the technological diversity associated with the environment into which buyers and suppliers are inserted affect the forms of co-operation among them. The second hypothesis assumes that industrial networks should be seen as inter-organisational forms that require a complex integration of productive activities, competencies and knowledge, being based in institutional arrangements that reflect this complexity. The third hypothesis would be related to economic impacts of co-operative links in these networks. Specifically, we assume that those impacts can be related to three main elements: (i) the increase of technical-productive efficiency; (ii) the strengthening of inter-organisational co-ordination to face environmental uncertainty; (iii) the increase of dynamic efficiency through the generation of technological innovations. On this basis, the main objectives of the analysis can be identified. The first involves the definition of objective criteria to map the institutional diversity of industrial 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 industrial networks with basis in the criteria previously defined. Finally, the third objective involves a characterisation of network *modus operandi* in 'stylised models' of structures, considering the impacts of inter-firm cooperation previously mentioned.

The article is divided in five sections, besides this introduction. Section 2 discuss some aspects related to a methodological perspective based in the concept of 'industrial networks'. Section 3 discuss some elements related to the technological diversity of the environment in which industrial networks are inserted, whose combination will be used to characterise some 'stylised models' of structures. Section 4 presents the basic characteristics of those 'stylised models', as well as some elements that can be used to discuss the impacts of inter-firm co-operation in them. The next section (Section 5) tries to use this analytical framework to discuss those impacts in the 'stylised models' mentioned. Finally, the concluding section (Section 6) identifies some lines of investigation which could be explored in the future.

2 - The concept of 'industrial networks' as an analytical cut

The concept of 'network' has been increasingly used by different sciences that have to deal with the complexity of the subject studied. '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 related the structure of a network to internal flows that are interchanged between nodes through specific links. 'Network analysis' tries to describe the structure of links among nodes, the flows associated to these links and the location of the resultant arrangement into a macro-environment, as well as the undercurrent of its development and evolution (Figure 1). The network approach incorporates several ideas originally formulated in the modern sociological literature, which develops concepts in order to discuss the consolidation of social groups (Granovetter, 1995). The basic hypothesis of this analysis is that the configuration of present and absent links among actors inserted in social arrangements reveals specific structures. Relationships among actors in 'social networks' are supposed to perform an extremely important role, either from the point of view of social systems or through the consolidation of cognitive patterns which guide agents´ behaviour.

In the field of economic theory, network analysis has been correlated to a theoretical perspective which stress a point neglected in neo-classical analyses: the social dimension of inter-firm relations. Contrasting with the neo-classical view, it is supposed that economic agents' behaviour can be affected by the social relationship structure they are inserted, which withdraws them from maximising rational actions, resulting in the acquisition of habits and routines that decisively condition its behaviour. In this sense, network analysis is developed from a critic of the artificial division between the economic agent and the external environment. It is assumed, therefore, that this environment is institutionally structured, with basis on social bonds among agents. Considering the relevance of these bonds, two implications can be singled out: (a) the behaviour of an agent cannot be disassociated from the others with which it establishes systematic interactions (as suppliers and customers); (b) the market should not be seen as an amorphous and abstract 'locus', but as an institutionally structured environment, which is gradually modified through the relationships between the agents. The concept of 'embeddedness' (Grabher, 1993; Hollingsworth et alli, 1994) - traditionally used is this kind of approach - refers to influences established between the relationship structure and agents´ behaviour, being related to an economic environment with institutional specificities.

The network approach can be extended to the economic relations between firms in productive chains, being associated with 'industrial networks' in which the generic morphological elements of 'networks' - nodes, positions, links and flows - assume a specific character (see Figure 1). The concept of 'industrial networks' mirrors not only the recuperation of themes approached by classical political economics - discussing the specificity of the 'division of work' among firms in an advanced capitalistic society - but also contributions from other fields of knowledge[1], with basis in an interdisciplinary approach through which economics has absorbed concepts from other sciences which are helpful in the understanding of economic phenomena. Network analysis tries to describe the structure of co-operative links among firms and its location into the economic environment, as well as the undercurrent of its development and evolution along time[2].

The concept of industrial networks presupposes that the nodes which compose the structure can be related to firms with specific characteristics, while the relations which 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 the consolidation of specific productive, technological and organisational competencies - which condition the possibilities of a mutual interaction among them. These arrangements implies certain investment efforts, resulting in specific sunk-costs to the relation and in rigidities that reinforce the links among firms along time. At this level, a network analysis tries to identify the relevant organisational characteristics of the agents involved, as well as to map the relationships established among them.

Industrial networks consists not only of actors and relationships, but also of certain activities/resources. In fact, we can observe the integration of multiple activities (production, commercialisation, R&D etc) at the network level, generating a functional interdependence - associated with a specific division of work - that reinforces the cohesion of the arrangement. At this level, the analysis has to deal with the diversity of functional activities integrated in network structure, involving a description of intra-network productive chains. Specifically, the interdependence between network members can be related to a specific 'division of work' that connects the different activities performed by them. According to Johanson and Mattsson (1987, p.256), the internal 'divison of work' of industrial networks performs a critical role, involving specific mechanisms of co-ordination.

We can also stress the relevance of some 'internal flows' that connected the agents inserted in industrial networks. These flows involve two-way exchange processes which

---

[1] These contributions involves not only elements of modern sociological theories, associated to the consolidation of 'social networks", but also contributions from physics and mathematics - such as the cluster analysis and the theory of graphos - which play an important role in the discussion of the morphological characteristics of these networks.

[2] It is possible to differentiate several kinds of networks in function of the phenomenon approached. The concept of 'industrial networks', for instance, is more directly associated to the consolidation of productive systems, involving a greater mobilisation of resources and a specific division of productive functions among network agents. On the other hand, 'innovation networks' are generally associated to arrangements that are assembled with the specific aim of viabilizing an interchange of competencies, accelerating innovative processes and being associated to a smaller immobilisation of resources and to a more fluid definition of agents' role.

form the backbone of the networks (Easton e Lundgreen, 1993, p.90). 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. Specifically, we can observe the existence of recurrent transactions among network members, based on multiple contractual forms and onn distinct temporal horizons[3]. Those transactions generally involve specific assets, which, in order to be generated, require the integration of technical and organisational competencies. Considering this aspect, the analysis of transactions established among network members can be seen as an important aim. On the other hand, industrial networks also involve the consolidation of a pool of information that are shared among their members, requiring the assembling of language codes and communication channels, with the aim of making viable the transference of knowledge and competencies among them[4]. At this level, network analysis should identify the informational infra-structure of the arrangement and the nature of the information that is transmitted through this infra-structure.

3 - Technological complexity and inter-firm relations

The possibility of enhancing inter-firm co-operation is strongly conditioned by the characteristics of technologies employed. In fact, co-operative arrangements based in the share of productive functions among partners do not emerge in a vacuum, being strongly conditioned by the complexity of the technologies that have to be mobilised. According to Joly and Mangematin (1995, p.38), we can identify two general trends that explain the increase of technological complexity of the environment in which firms are inserted. The first is related to 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 is be related to an increase in the set of knowledge and skills that must be integrated to make production feasible. Considering these trends, we can suppose that the more 'complex' is the technological environment in which the firm is inserted, the more important will be the access to

[3] Those structures involve indefinite and sequential transactions, performed in a context of a general pattern of reciprocity. This pattern is associated to an undefined temporal horizon, more based in implicit obligations than in explicit ones. As a consequence, we can observe the consolidation of a strong interdependence among agents, distinct from the independence which prevails in commercial transactions and from the hierarchic dependence which prevails in intra-firms relationships. Along time, that inter-dependence allows the consolidation of a mutual orientation, which is manifested in a common language regarding technical matters, contracting rules and standardisation of process, products and routines.

complementary assets and competencies. In a 'dynamic' environment the necessity of this will be still greater, due to technological changes that could affect the competitiveness of firms.

Lundgren (1995, p.77) emphasises the interconnections between the evolution of industrial networks and the technological environment in which they are inserted, stressing the importance of the interplay between technological systems and network structure and evolution. In this sense, the concept of 'technological systems' seems particularly useful to delimitate the technological environment in which industrial networks are embedded. Carlsson and Stankiewicz (1991) correlate the concept of 'technological systems' to interactions of agents in a specific industrial area that can be associated to a particular institutional infrastructure or set of infrastructures, which are particularly involved with the generation, diffusion and utilisation of technology. According to them, these systems should be defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. We can combine the more 'institutional' definition of technological systems developed by Carlsson with other definitions that emphasise the intrinsic technological characteristics of those systems. Maisseu (1995), for instance, correlates the characteristics of technological systems with some properties of the product generated. Specifically, this product could be seen as a 'system product' that may be understood as an organised complex whole, based in an assemblage or combination of parts forming a complex or unitary whole. A product is thus defined as a structured system revolving round a principle, being based in an aggregation of elements ordered with a view of fulfilling a previously defined objective. According to this view, a 'system-product' can be broken down into subsets defined with basis in a 'functional' classification. Considering their degree of complexity, these subsystems can also be broken down into components which are made up of elementary technical objects, defined with a basis in a strictly technological classification.

Considering the complexity of 'system products', Maisseu identifies three elements to differentiate the components and their embodied technologies: (i) the relevance (relative share) of the components in terms of the overall cost of production; (ii) the degree of maturity of technology embodied in components; (iii) the relevance of the component in terms of some criteria of functional performance (related to the utility and quality associated with it). According to these elements, four kind of components could be identified (Table 1). First, we can identify *trivial* components, with little influence on the properties and quality of the product and to which the cost is relatively small compared with the total cost of the product. Trivial components are also based in mature technologies, widely available and hence commonplace. Second, we can identify *basic* components with a considerable influence on the product. The total cost associated to these components plays an important place in setting product's cost. They are also

---

[4] These networks involve a collective treatment of information and a process of solution searching and learning, which results in the creation of a common denominator in terms of available information and expertise retained by the agents, permiting to face the environmental turblence in a co-ordinate way.

based in mature technologies mastered by a number of other competitors. Due to the standardisation of these components, any inefficiency in the provision of them negatively affect the performance of the product. Third, we can identify *critic* components, to which the function performed can determine the decision of purchase, without the cost of the component being necessarily dominant in the total cost but being the essential element determining product characteristics, properties and final quality. The embodied technologies in these components are usually in their early or fast growth stage, strongly affecting the performance of the product. Finally, a fourth kind of component, called *key* component, can be identified, combining the different characteristics previously mentioned: its cost may be relatively high in the make up of total costs, its characteristics may be a determining factor in the functional performance of the product, and the distribution of its constituent technologies may still be limited because they are in their early or fast growth stage or because they are protected by patents.

Another important contribution to the understanding of technological systems can be found in the analysis of Lundgreen (1995, p.94). He uses concepts originally developed by David (1987) to associate these systems with the idea of 'technical connectedness' and to prospects of economic benefits from 'system integration'. This definition stress not only some aspects traditionally associated to the performance of industrial activities - such as the presence of scale and scope economies in the production of inputs and goods and the relevance of different learning mechanisms - but also two other key-concepts: (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.

The concept of 'technological interrelatedness' can be linked to the discussion about the 'complexity' of technological systems. Despite the difficulty in finding a generally accepted definition of 'technological complexity in the literature, we may consider the relevant contributions of some authors. According to Singh (1997), three characteristics can be extracted from these contributions. The first is related to the 'systemic character' of complex technologies, which means that a complex product or technology comprises 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 - between components within subsystems, between components across subsystems and between subsystems at various hierarchical levels. The third characteristic is related to the 'nondecomposable' 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.

According to Kline (1991), it would be possible to estimate an index of complexity of technologies and ‘sociotechnical systems’ by the aggregation of three measures: (1) the number of ways changes can occur within technological systems; (2) the number of components which must be chosen in order to design the technological system; (3) the number of control modes in the technological system plus those that connect the system to its surrounding environment. The third measure seems particularly important, involving feedback mechanisms which result in system modification or adaption. Henderson and Clark (1990), in a classical work, deal with the same subject, using the concept of ‘product’s design architecture’ to define the patterns through which components and sub-systems interact with each other. Specifically, they discuss the differences between four types of innovation associated with the morphology of industrial systems (Figure 2): (1) incremental innovations that introduce relatively minor changes to existing product, exploiting the potential of established design and reinforcing the competencies in both product architecture and component technologies; (2) modular innovations based in the introduction of a new component technology inserted within an essentially unchanged product architecture; (3) architectural innovations based in the reconfiguration of an established system to link together existing components in a new way, often triggered by a change in some components that creates new interactions and linkages with other components in the established product; (4) radical innovations that establish a new dominant design and, hence, a new set of core design concepts, embodied in components that are linked together in a new architecture.

Another interesting contribution to the characterisation of the ‘complexity’ of industrial systems can be found in a recent work of Sanchez and Mahoney (1996, p.66). Using the concept of ‘nearly decomposable system’ originally formulated by Simon (1962), they emphasise that product designs differ fundamentally in the degree to which they can be decomposed into ‘loosely coupled’ vs. ‘tightly coupled’ components. In this sense, ‘modularity’ would be a special form of design which intentionally creates a high degree of interdependence or ‘loose coupling’ between components, by standardising component interface specifications. Connecting the concept of ‘modularity’ which the notion of ‘product architecture’, Sanches and Mahoney define a ‘modular product architecture’ as a special form of product design that uses standardised interfaces between components to create a flexible product architecture. In terms of industrial networks, two analytical unfoldings can be identified in this perspective: (1) the standardised component interfaces in a modular product architecture provide a form of embedded co-ordination that greatly reduces the need of managerial authority, in order to achieve a co-ordination of productive flows and development processes; (2) the increase of productive flexibility through different combinations of new or existing modular components results in the need to co-ordinate a network of component developers and suppliers.

Langlois and Robertson (1992, p.301) also emphasise the potential benefits of modularity in technological systems, pointing out that a decentralised network based on modularity can have advantages in innovation to the extent that it involves the trying out of many alternative approaches simultaneously, leading to rapid trial-and-error learning. Among the benefits of modularity, we can mention: (i) the emergence of multiple entry points for new ideas, progressing faster technologically especially during periods of uncertainty and fluidity; (ii) the implementation of a division of work that generates stimulus to autonomous innovation, allowing specialist producers (and sometimes specialist users) to concentrate their attention on particular components; (iii) the possibility of identifying technological bottlenecks in the production of components that can be converted in focal points for technological changes.

However, not only the complexity of the 'technological systems' affects the structure of industrial 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 in the consolidation of 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' which require the integration of complementary competencies has induced different forms of technological co-operation between firms. In fact, since these innovations require the integration of different and heterogeneous technologies and expertise, firms usually have to cope with technological disequilibrium and technological bottlenecks. When the number of relevant technical fields increases and new requirements for technical advances arise, firms are bound to face a kind of 'capability squeeze' (Imai and Baba, 1989), which reinforces the importance of technological co-operation with other agents with complementary competencies.

To discuss the connections between the complexity of relevant knowledge and the emergence of industrial networks, the concept of 'technological regime' developed by Nelson and Winter (1982) and Malerba and Orsenigo (1993) seems particularly useful. Specifically, different technological regimes can be seen as a particular combination of: (i) opportunity conditions; (ii) appropriability conditions; (iii) degrees of cumulativeness of technological knowledge; (iv) characteristics of the relevant knowledge base. According to Malerba and Orsenigo (1993), there is a process of co-evolution between the characteristics of technological regimes, the technological strategies adopted by firms and the (inter) organisational forms suitable to the acceleration of innovative processes. We can identify three characteristics of 'technological regimes' that affect more directly the possibilities of co-operation between firms: (i) the cumulativeness of technological knowledge in each regime; (ii) conditions of appropriability related to technological innovations generated; (iii) characteristics of the relevant knowledge base that has to be activated to generate technological innovations.

The concept of 'cumulativeness' deals with connections between presenr day innovative efforts and the innovations that could be obtained in the future. An 'inter-organisational level' of cumulativeness could be characterised, which would be related to the importance of interactive learning mechanisms to the innovative process. In that sense, Johnson and Lundvall (1992) postulate the following hypothesis: (i) interactive learning involves a social process, from which basic language concepts are developed among agents; (ii) the more complex the learning, the more will be the required interactions to viabilize it; (iii) the deepening of interactions requires the improvement of inter-communication codes and channels among the agents involved; (iv) the continuity of the interaction introduces the possibility of new combinations for different kinds of knowledge. Specifically, we can suppose that in regimes where interactive learning mechanisms play a relevant role (being based in cumulative mechanisms), the pre-existence of co-operative links among agents with complementary competencies and skills become an important advantage *vis-à-vis* outsider agents. Conditions of appropriability also affect the possibilities of inter-firm co-operation in two main senses. In situations where these conditions are relatively well-defined - and where the integration of multiple competencies seems to be important - the creation of co-operative arrangements will be easier. Otherwise, in situations where the conditions of appropriability can not be properly defined *ex-ante*, the consolidation of principles of mutual trust seems to be crucial to permit the integration of competencies that would be necessary to viabilize the generation of innovations.

The characteristics of the knowledge base that has to be activated to generate technological innovations also affect decisively the possibilities of co-operation between firms. A differentiation between three dimensions is particularly helpful in understanding these impacts. 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 viabilize a systematic inter-change of communication 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 as instruments to facilitate the 'codification' of tacit knowledge, which would be related to a process of reduction and conversion that render especially easy the transmission, verification, storage and reproduction of knowledge. In this sense, the skills necessary to understand and use the local codes will often be developed only by those allowed to join the network and take part in the process of interactive learning.

The second dimension involves characteristics of different kinds of knowledge that are relevant in each technological regime. In thise sense, Lundvall and Johnson (1994) propose a distinction between four different kinds of knowledge: (i) 'know-what' associated to knowledge about 'facts', involving the transmission and storage of information; (ii) 'know-why' associated with techno-scientific principles and basic laws of motion in nature, in the human mind and in society; (iii) 'know-how' associated to specific skills and capabilities to do something, not only in the productive orbit but also to many other activities in the economic sphere; (iv) 'know-who' involving a mix of social skills that give information about who knows what and who knows how to do what. These different kinds of knowledge take place through different channels, involving social practices developed in specific communities. In the industrial world, the consolidation of those communities - at an inter-organisational level - could be linked to the emergence and consolidation of industrial networks.

The third dimension of the knowledge base 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 to make easier this integration[5]. On the other hand, 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.

4 - Industrial networks and technological diversity: a tentative typology

Based on this preliminary systematisation effort, some 'stylised models' of industrial networks can be characterised. In order to capture the heterogeneity of these arrangements, it is important to have two points in mind. The first involves the diversity of technological dynamics in the industries networks are inserted. In this sense, it is useful to consider the systematisations made by authors like Pavitt (1984 and 1990). Our analysis suggests that the specificity of the technological dynamic in each sector strongly conditions the set of complementary assets and skills that are seen as relevant by the actors inserted in them, affecting in a decisive way the characteristics of co-operative arrangements. The second point is more directly associated with some specificities of the technologies that have to be mobilised at the network level. In this sense, two main elements might be 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

[5] Malerba and Orsenigo (1993, p 66-69) stress that the menu of viable co-operative arrangements between firms becomes wider as technological opportunities are more 'pervasive' - involving the application of a core technical knowledge to a variety of products and markets - and the knowledge base is increasingly complex.

productive activities performed; (ii) the complexity of 'technological regimes' related to the environment in which networks are inserted, particularly in terms of the diversity of knowledge bases, competencies and skills that must be mobilised to generate innovations. According to these criteria, four types of industrial networks can be characterised (Figure 3):

(i) **traditional subcontracting networks**: related to traditional industries, involving non-complex products, which can be produced in small-scale units, and a knowledge base relatively simple. In this kind of network 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 suppliers, which results in the decrease of production costs and in the increase of productive flexibility. Interactions between buyers and suppliers tend to be mediated by the pre-definition of orders, involving an evolution - and sophistication - of traditional 'putting out' system, with a limited interchange of information between network members. 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) **modular assembly networks**: related to mass-production products with a 'modular architecture' of components and sub-systems, reflecting a high complexity of the respective 'technological system'. The large-scale production involves a complex hierarchy of components that have to be integrated at the network level. A classification of components (trivial, basic, critic and key) according to their relevance in the 'architecture' of the product could be obtained in this kind of arrangement. 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 equipments 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, being based in the possibility of increasing the range of products due to changes in the components integrated in a 'modular architecture'.

(iii) **complex products networks**: oriented to the production of 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 requires 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. The possibility of classifying different components according to their relevance in the 'architecture' of the product is more complicated in this case, because these components must be previously integrated in semi-autonomous sub-systems. Competitive gains generated are usually related to high performance customised solutions, attending specific demands of sophisticated buyers.

(iii) **technology-based networks**: associated with 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 - associated to characteristics of 'technological systems' - is relatively low, in the sense that the critical activities in the productive chain are performed by 'high-technology firms', who specialise in specific fields of knowledge, which perform a central role in the innovative process. In contrast with other models, these arrangements do not involve hierarchies of components and sub-systems. In fact, they are based on an integration of complementary competencies with the aim of viabilizing the development of specific technologies that present an attractive economic potential. Examples of high-tech industries such as biotechnology, opto-eletronics, new materials, semiconductors and (in some sense) software have been recurrently related to this kind of arrangement.

The typology constructed tries to capture the institutional diversity of industrial networks. In this sense, two observations must be stressed. The first involves the possibility of an evolution from one 'model' to another. This process can occur because of innovations that generate relevant changes in the characteristics of the 'technological systems' associated with those industries. The second observation is related to the process of network evolution. Basically, the evolution of industrial networks along time can be associated to interactions established among three different levels (Karlsson and Westin, 1994). The first refers to the macro-structure in which the network is inserted, involving wider environmental elements that affect networks evolution. The second refers to specificities of networks internal processes, through which the arrangement morphology is modified to answer environmental stimuli. The third level is related to the behaviour of network agents, involving the incorporation of 'networking principles' to entrepreneurial strategies. Among those levels, particular importance must be attributed to network internal processes, which conform a *modus operandi* that strongly affects the evolution of the arrangement over time.

The description of industrial networks *modus operandi* requires the identification of some dimensions of co-operative links that characterise those structures. Networks' *modus operandi* could be correlated to three dimensions: a process of techno-productive co-operation between firms; a process of inter-organisational co-ordination of their actions; and a process of technological co-operation, specifically related to the integration of competencies and to joint innovative efforts. In the productive orbit, it is important to consider the tools mobilised to raise productive efficiency and flexibility at the network level, explainnig how the consolidation of a specific 'division of work' among network members generates technical gains, creating competitive advantages to them[6]. In the inter-organisational orbit, the consolidation of industrial networks can be associated to the creation of a *governance* structure that makes easier the adaptations required in face of market changes[7]. Finally, in the technological orbit, industrial networks can be related to the creation and circulation of knowledge and information, generating a collective learning process which widens the innovative potential of the arrangement, through the integration of complementary competencies and skills[8].

To develop the discussion about the *modus operandi* of industrial networks, some elements related to the dimensions previously mention will be used. The 'techno-productive co-operation' will be discussed based on the following elements: (i) general characteristics of productive chains associated with each kind of arrangement; (ii) specific attributes of the products generated at the network level; (iii) technical-productive gains that can be obtained as a consequence of the division of work and firms' specialisation at the network level. The process of 'inter-organisational co-operation' will be discussed based on the following elements: (i) a description of the typical relations between firms in each kind of arrangement; (ii) a characterisation of *governance* structures related to network environment, emphasising the

[6] Five main factors related to technical gains can be stressed: (i) the increase of labour and capital productivity at the network level; (ii) improvements in the quality of products generated, resulting from the adoption of certification and others procedures among network members; (iii) the compatibilisation of technical standards at the network level; (iv) gains related to the customisation of products generated according to the needs of individual customers, integrating technical competencies of network members; (v) the increase of product flexibility, through the generation of a product mix that reinforces the ability to deal with the differentiation and volatility of markets.

[7] More than a 'idealised' (hybrid) form of governance, localised between the integrated firm and the atomised market, industrial networks could be related to different mechanisms of co-ordination. Specifically, we can associate the governance structure of industrial networks with the power structure that prevails in these arrangements and with the co-ordinative capabilities that are constructed in order to face environmental turbulence.

[8] 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, through joint R&D activities performed by network members. Second, the competencies of network members tend to be upgraded in a co-ordinate involving an equalisation of capabilities and skills that requires not only joint efforts, but also the creation of specific institutions. Third, there are specific mechanisms of knowledge circulation inside the network which permits a reduction of

centralisation of internal flows and the hierarchisation of intra-network relations; (iii) a description of the main forms of co-ordination that are mobilised at the network level, emphasising the subject of this co-ordination and the contractual basis in which they are based. Finally, the process of 'technological co-operation' will be related to the following elements: (i) characteristics of informational flows inside the network; (ii) characteristics of interactive learning mechanisms in each kind of arrangement; (iii) characteristics of joint innovative efforts performed by network members, emphasising the technological innovations generated and the the 'division of work' associated with those efforts.

5 - Industrial networks *modus-operandi*: an analysis of 'stylised models'

5.1 - Traditional Sub-contracting Networks

These networks can be related to productive chains with dense sub-contracting relations between assemblers and suppliers, 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. Examples of these kind of arrangement have been exhaustively described in the literature, being associated with traditional industries, such as textile, shoes, furniture, metal craft and food. The model of 'Third Italy' industrial districts has been recurrently related to this kind of arrangement.

A systematisation of the characteristics of this kind of network is presented in the Table 2. 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 through this kind of arrangement have usually low value, low volume and a simple design. They are usually releted to industries that do not deal with complex technologies, in which the main font of technical progress comes from outside, involving the supply of equipment and other inputs. The products generated tend to present a high variety, based on different combinations of components. They can be related to high tolerance margins in terms of productive procedures and quality level. These products involve a limited number of

---

innovation lags and an acceleration of incremental innovations. Fourth, we can observe stimuli to the diffusion of technological innovations among network members, which are based in close links established between them.

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. Despite the possibility of others gains, the reduction of production costs tends to perform a critical role in the establishment of those networks. 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.

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 specific 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[9].

In terms of the 'governance' form, these networks usually involve dispersed structures with a low level of hierarchisation, 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. These networks can be seen as an evolution of the traditional 'putting out' system, involving interactions mediated by pre-definition of orders that might be attended by suppliers. The co-ordination of internal flows involve 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

[9] According to Schmitz (1994), the concept of collective efficiency could be linked to two aspects: (i) the exploitation of external economies related to the agglomeration of productive activities and services, which proportionate incidental gains; (ii) the adoption of joint actions at the level of the network, which proportionate deliberate gains associated with the co-ordination of the productive and technological efforts made by network members.

alternatives are usually based in short-term contracts that hardly include incentive mechanisms oriented to the generation of technical-productive gains in the orbit of the supply chain.

The informational connections between firms tend to be less sophisticated than those associated with other forms of industrial networks. Specifically, informational flows involve a non-systematic interchange of information about performance and quality of components. As a general tendency, informational flows between assembler firms, dealers, retailers and distributors tend to be more relevant than the flows connecting these agents with the net of suppliers. 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 according to those tendencies.

Interactive learning mechanisms perform an important role at the network level. 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.

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. Innovative efforts with a more formal character also have some specificities in these networks. They are usually based on a centralisation of design activities in assembly firms or dealers, involving limited functional improvements of products generated and design variations in components that might be attended by the net of suppliers. Despite these general characteristics, we can identify some 'niches' in the industries associated with these networks that produce extremely sophisticated goods from a technological point of view, such as sports shoes. In these segments, design activities are centralised in large assemblers, requiring a high level of technological competence.

5.2 - Modular Assembly Networks

These networks involve a variety of actors that interact in productive chains, being related to the sophistication of sub-contracting arrangements in 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. Generally, these networks are based on a process of disverticalisation of large firms, induced by technological factors or by competitive stimuli. This process tends to be accompanied by the development of products with a modular architecture of components and sub-systems. As a consequence, sub-contracting relations between suppliers and assemblers have suffered important qualitative changes, inducing productive and technological co-operation. Examples of this kind of arrangement have been particularly related to changes that can be observed in the automobile industry, involving the incorporation of principles of modularity in the organisation of production and in the relations between assemblers and suppliers[10]. Table 3 presents a systematisation of the '*modus operandi*' of these networks.

Products generated by this kind of arrangement 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, which are integrated through linear-linked mechanisms. The integration of components is usually based in 'modular architectures' that permit different combinations of them in similar platforms, generating a large variety of products. The technical sophistication of products and components results in low tolerance margins to the different activities performed in productive chains. The 'division of work' in productive chains can be related to the integration of different components and sub-systems in a modular architecture, in order to generate products that attend to 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.

[10] According to the *Business Week* (April 7, 1997, p.49), one of main targets of Toyota's strategy is the company's PC 21 program that intends to produce a modular engine with fewer parts, made a cost one-third lower than current engines. Simultaneously, Toyota has reduced the cycle of development of new models to less than 15 months, as a consequence of the incorporation of principles of modularity in its cars. American companies have followed suit. According to Tully (*Fortune*, February 8, 1993), Chrysler is the most impressive example of this kind of adaptation. In fact, Chrysler has avoid buying thousands of separate items, designing cars to be built in modules and establishing productive links with suppliers not to deliver piecemetal components but pre-assembled sections such as complete antiblock brake systems and door panels. The Chrysler Neon, for example, uses numerous modular assemblies parts. Dyer (1996) presents an interesting analysis about how supplier-management practices have changed at Chrysler in the recent years, due to the incorporation of principles of modularity in its cars. In the case of Ford, the same process of "modularisation" can be observed, with the Taurus platform design being leveraged to provide a basis for the Taurus and Mercury Sable sedans and wagons and for the Ford Taurus Windstar minivan. The same tendency can be found in European companies: Volkswagen, for instance, has implemented a platform consolidation plan with the aim of

Mass customisation could be seem as a more advanced stage of a continuous improvement process, linked to an architecture that involves different modules, permitting them to integrate rapidly in the best combination or sequence required to tailor products.

Technical-productive gains that can be obtained in these networks are usually associated with the simultaneously generation of economies of scale and scope in the productive chain. 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, it is necessary to focus on total value chain improvement, as well as substantial investments in productive co-ordination mechanisms and dedicated assets. Three aspects seem particularly important to achieve this kind of gain: (i) a sophisticated level of automation which allows for operation of CIM (computer-integrated manufacturing) systems; (ii) technological developments in product design, based in the increase of modularity of components; (iii) the sophistication of the manufacturing of sub-assemblies and parts.

The increase of reactivity in face of market changes is also an important aspect of technical gains obtained in these networks. This reactivity is based on a productive flexibility associated with the diffusion of just-in-time practices in inter-firm relations and with the generation of a wide range of products with basis in the principles of modularity. This point is particularly emphasised by Coriat (1995, p.224-225) in a characterisation of 'regimes of variety', seen as flexible mass production systems that combine economies of scale and differentiation in such a way that they can manage both flexibility of demand and strategies of differentiated supply. The implementation of total quality control systems between assembler and suppliers is also a pre-requisite of the consolidation of this kind of regime. As a consequence, the performance of suppliers tends to be evaluated with basis in complex mechanisms, involving certification practices, carried out in accord with specific protocols that try to built new routines in inter-firm relationships.

The *governance* structure of these arrangements is based on the central role performed by a core assembler positioned in the apex of the network. It is also very common a hierarchization of suppliers of sub-systems and components in different levels - first-tied suppliers, second-tied suppliers, etc - according to their technical expertise and to the intensity of their interaction with the core assembler. We can also identify different patterns of co-ordination of productive links 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 character of the process of co-ordination[11]. When the process of exchange between suppliers and assembler gains a multidimensional dimension, the responses

---

having similar-size models from all VW brands - VW, Audi, Seat and Skoda - sharing thousands of common parts, from steel floor parts to windshield-wiper motors (*Business Week*, February 25, 1996).

[11] For a discussion of this process in the automobile industry see Liker, Kamagh, Wasti and Nagamachi (1996).

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.

In these networks, the mechanisms mobilised to co-ordinate the actions of firms (assembler and suppliers) are very complex. At the productive orbit, these mechanisms involve sophisticated methods of production planning and a widespread use of protocols based in just-in-time principles, with the subcontractor being perfectly integrated into the manufacture's production cycle (Coriat, 1995, p.218). The mechanisms of intra-network 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. In terms of their contractual basis, the mechanisms of co-ordination are strongly based in long-term contracts with specific incentive mechanisms to stimulate the increase of productivity-quality of components generated.

In terms of technological co-operation, these networks can be related to a sophisticatisation of the informational flows. Specifically, informational feedbacks 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 at the architectural level 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 infra-structure (EDI dedicated systems, for example) and being associated with the development of specific codes of communication.

Interactive learning mechanisms associated with relations between assemblers and suppliers are particularly relevant in these networks. In this sense, four 'outcomes' of interactive learning 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 can be related to 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 in the ‘modularity’ of the architecture in order to facilitate the integration of new components and sub-systems.

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). This process is relatively new. 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.

5.3 - Complex Products Networks

These networks involve 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 that are produced as one-off items or in tailored batches for individual customers. The products generated present a high level of technical complexity, involving the integration of of semi-autonomous sub-systems, sometimes based in very different technologies, as well as the 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. Due to the diversity of sub-systems that must be integrated at the product level, these networks are usually related to 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. Examples of this kind of product described in the literature involve 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. Table 4 presents a systematisation of the ‘*modus operandi*’ of these networks.

These networks are created with the objective of integrating components, subsystems and software, in order to generate customised products that attend specific demands in terms of performance, capacity and reliability. Competitive gains are usually associated with high performance customised solutions for specific demands of sophisticated buyers. Among the technical-productive gains that can be obtained, we can mention: (i) the reduction of cost and lead-time of complex projects with the use of parallel engineering; (ii) specialisation gains in the production of sub-systems, due to the specialisation of suppliers; (iii) the increase of functional performance of products generated, through the integration of hardware and software; (iv) customisation gains based in a process of technical co-ordination promoted by 'systems integrators'. The productivity and efficiency of this kind of production are strongly linked to a experience in the management of complex projects, being based in the integration of multiple competencies and in horizontal interactions that permit a continual readjustment and redefinition of tasks. To make these adjustments feasible, 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.

From the (inter)organisational point of view, 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 network *modus operandi*. 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 in specific projects with a transitory character in which we can observe a previous definition of tasks to be performed by network members We can also observe a hierarchization of the 'governance structure' of the network, according to the diversity of components and sub-systems that must be integrated at the project level. 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 many horizontal interactions to make compatible the technologies used in different points of the network. 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 viabilize new projects or to correct some aspect of projects already finished, due to specific demands of the buyers.

The co-ordination of internal flows is the main function of 'systems integrators'. This co-ordination involves specific project management techniques. The process of co-ordination usually involves few large transaction between 'systems integrators' and a net of sub-systems suppliers. Transactions tend to be based in incomplete contracts between the parts, involving negotiated prices that often act as 'incentive mechanisms' to the increase of productivity. In the process of co-ordination, we can also observe an intense use of information technologies and new software techniques, 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 technical performance. Specifically, this co-ordination involves the establishment of productive and technological links that progressively induce the consolidation of a 'new' market, related to the 'complex product' generated. Thus, non market mechanisms play an important role in the co-ordination of economic activities, which is based in inter-firm *ex-ante* co-operation, agreement and negotiation of technical issues related to the stages of design, development and manufacture.

The 'complex' character of products generated through these networks 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 and be maintained and deepened in the next stages. Second, we can mention the intense interchange of information about sub-system proprieties in the implementation of projects, 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. These flows are particularly important to integrate some 'intangible' technologies at the network level, increasing the performance of network activities. Finally, we can mention informational flows related to a sophisticated technical assistance developed between users and 'systems integrators', related not only to adaptations that permit an increase of products' performance (incorporating a new software, for example) but also to an eventual replacement of the product by a new model, originated from new projects.

The density of informational flows results in the deepening of interactive learning mechanisms at the network level. Some impacts of these mechanisms may be pointed out. First, they tend to facilitate the customisation of products according to users needs. Second, interactive learning mechanisms tend to reinforce the competencies of 'systems integrators' along time as a sub-product of the projects implemented. Third, those mechanisms permit the consolidation of 'markets' that can not be based in arms-length transactions. Finally, those mechanisms induce the consolidation of temporary multi-firm 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 and the nature of co-ordination processes are extremely different from other types of networks, especially those that involve mass products based on standardised components. According to Hobday (1995 and 1997), the dynamics of innovation in these networks is strongly based on complex interfaces between components and sub-systems and on an active involvement of users. Some characteristics of innovative efforts must be pointed out. Basically, these 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. In fact, as a result of the non-linear proprieties of inter-dependent sub-systems, the 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 a product architecture. In this sense, the integration of hardware and software to attend specific needs of users becomes an important element of innovative dynamics. We can also emphasise two others aspects of innovative efforts. First, they involve a strong user-producer involvement, in a way that is 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.

5.4 - Technology-Based Industrial 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 set of components and sub-systems to be technically integrated in order to generate a specific product. In this kind of arrangement the 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’. Table 5 presents a systematisation of the *modus operandi* of these networks.

Products generated through these networks usually have high value and low volume, being based on a high-intensity of R&D efforts and on a complex knowledge that is embodied in them. The ‘emergent’ character of the markets reinforces the relevance of the access to complementary competencies, in order to facilitate the setting of the product to the market. 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. 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-productive gains. First, we can mention the reduction of lead-time associated with the transition R&D-production due to the interchange of information between network members involved with different stages of the process. Second, 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. Third, 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. Fourth, 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.

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. Sometimes these firms establish subcontracting relations with other agents as a supplier (when they interact with a end-user sector of the technology to be developed, as occurs in the relations between biotechnology firms and pharmaceutical companies), sometimes as a buyer (when they interact with agents inserted in the scientific-technological infra-structure, as Universities and Research Institutes)..

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. 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. 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'.

The forms of co-ordination assume a specific character in this kind of network. In the phase of network's consolidation, 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 appropiability conditions of the innovations generated. We can also mention a tendency to a progressive 'formalization' of co-ordination mechanisms and of the contractual basis that orients the relations between firms. Situations in which this process of 'formalization' has been combined with the progressive 'centralisation' of network structure are very common. 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.

The informational flows are usually very complex, involving feed-back loops between different R&D stages. These flows are often based in 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 an 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.

Interactive learning mechanisms that characterise these networks are strongly linked to a reduction of costs and lead-time 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. The deepening of 'learning-by-interacting' mechanisms between network members has also two important consequences. First, it facilitates the definition of 'appropiability 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.

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 difficult 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. The 'division of work' associated to R&D activities also includes specific efforts in the area of basic research, through which new relevant knowledge can be obtained. R&D process in these networks assumes a interdisciplinary character, involving not only a division of tasks between industrial firms but also strong interconnections with the technological and scientific infra-structure. In a general sense, network *modus operandi* 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. In this case, we can associate network internal flows and the transmission of stimulus between network nodes with an organisation of R&D activities based on the principles of the 'chain linked model' developed by Kline (1986).

6 - Conclusion: some analytical unfoldings

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

Another line of investigation which could be deepened involves connections between industrial networks and Industrial Policy. Specifically, the operationalization of policy actions should consider the institutional diversity of those arrangements and their relevance in the reinforcement of industrial competitiveness. Considering industrial networks as a reference set-up for the increase of productive efficiency and the dynamization of innovative capacity, public policy should try to create procedures which stimulates, strenghtens and consolidates them. Simultaneously, Industrial Policy should be able to monitor the evolution of these arrangements over time, identifying the vulnerabilities that need to be eliminated to reinforce industrial competitiveness. Finally, Industrial Policy should also signal possible opportunities to be explored by agents inserted in those networks, stimulating the strengthening of productive-technological links adequate to this aim.

Annex - Tables and Figures

Figure 1 - Analytical Approach

Network Approach (General Model)	**Industrial Networks Approach**
nodes	firms/activities
positions	division of work
links	organisational/productive/technological links
flows	transactions (tangible flows)/informations (intangible flows)

Table 1 - Classification of Components According to Functional Relevance

	Embodied technology	**Relative Costs**	**Utility/Quality Implication**
Key component	New	High	High
Critical component	New	Low	Low to high
Basic component	Mature to old	High	High (sometimes negative)
Trivial component	Mature to old	Low	Low

Source: Maisseu (1995)

Figure 2 - Modes of learning in production/creation processes

Learning about
Component Interactions
and Configurations

	Moderate	Significant
Moderate	**Incremental Learning at Component Level** Incremental learning through component development leads to limited functional improvements and design variations in components used in an existing product architecture.	**Modular Learning at the Component Level** Learning about new kinds of component technologies leads to significant changes in feasible component functions and designs that can be accommodated within an existing product architecture.
Significant	**Architectural Learning** Learning about new product market opportunities leads to new product architecture based on changes in the ways existing kinds of components are combined and configured in product design.	**Radical Learning at Architectural and Component Levels** Learning about new market opportunities and new product and component technologies leads to major changes in both kinds of components used and ways components are configured to form a product architecture.

Learning about Component Functions and Design

Source: Henderson and Clark (1990)

Figure 3 - Typology of Industrial Networks

Complexity of Technological Systems

	low	high
high	**Modular Assembly Networks** . mass-production products with a modular architecture . large-scale production with a hierarchy of components and sub-systems . competitive gains: products' differentiation and modularity	**Complex Products Networks** . 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	**Traditional Sucontracting Networks** . non-complex products associated to traditional sectors . small-scale production and inter-firm specialisation . competitive gains: low cost and productive flexibility	**Technology-Based Networks** . high-tech products associated to emergent markets . development of specif technologies with economic potential . competitive gains: innovative rents generated by new products

Complexity of Technological Regimes

Table 2 - Network Modus-operandi - Traditional Subcontracting Networks

Dimensions	Characteristic
I - Technical Productive Characteristics	
Basic Characteristic	productive chains associated with a density of sub-contracting relations between agents, based on the principles of 'flexible specialisation'. Vertical disintegration (at the firm level). Spatial organisation in 'industrial districts'.
Products' attributes	low value; low volume; high variety (based in different components); non-complexity; simple design; few components or architectures; high tolerance margins; different ranges of technological sophistication.
Objective of arrangement	generation of economies of specialisation in the production of inputs, parts and components, in order to reduce production costs and to adapt to a volatile demand. Implementation of collective actions that increase the efficiency of the arrangement.
Technical-Productive Gains	productivity gains in the production of components, associated with a process of technical specialisation. External economies associated to provision of technical services. Scope economies and productive flexibility at the level of assembly firms.
II - Inter-Organisational Characteristics	
Typical relations	relations established between semi-verticalized assemblers of non-complex products (shoes, textiles, etc.) and a network of firms responsible by the production of components, parts or by specific tasks in the productive chain. Possibility of intermediation by dealers.
Governance structures	dispersed structures with low level of hierarchisation, based on a functional specialisation among independent agents. Interactions mediated by pre-definition of orders. Evolution of 'putting out' model.
Forms of co-ordination	two alternatives: (i) co-ordination promoted by external agents (dealers) through the definition of new designs; (ii) co-ordination promoted by assembly firms at the end of productive chains, through definition of orders. Use of short-term contracts without incentive mechanisms.
III - Technological Characteristics	
Characteristics of Informational Flows	non systematic interchange of information about performance and quality of components. Previous definition of design and others products' attributes that must be attended by suppliers. One-way character of informational flows.
Impact of Interactive Learning Mechanisms	upgrading of products' and components' design. Diffusion of technical standards. Reduction of asymmetries in terms of productive efficiency. Diffusion of quality control procedures. Dissemination of modern organisational techniques.
Innovative Efforts Performed	incremental innovations based on learning mechanisms. Non-systematic character of innovative efforts. Centralisation of design activities in assembly firms or dealers. Limited functional improvements and design variations in components.

Table 3 - Network Modus-operandi - Modular Assembly Networks

Dimensions	Characteristic
I - Technical Productive Characteristics	
Basic Characteristic	productive chains associated with the integration of different components and sub-systems with basis in the principles of 'modular architecture'. Evolution of traditional mass production system. Spatial organisation in 'industrial poles'.
Products' attributes	high value; high volume; high variety; technical complexity; complex design; diversity of components and sub-systems; linear-linked components and architectures; low tolerance margins.
Objective of arrangement	generation of differentiated products through the integration of modular components and subsystems. Use of similar platforms to generate a large variety of products, with basis in the principle of 'mass customisation'.
Technical-Productive Gains	integration of economies of scale and scope. Reactivity to face market changes (productive flexibility), with the use of just-in-time practices. Modularity gains. Implementation of total quality control systems.
II - Inter-Organisational Characteristics	
Typical relations	relations that are established between large-assembly firms and a network of suppliers hierarchically organised, responsible for the production of components and sub-systems. Differentiation between relations with first-tied suppliers and second-tied suppliers.
Governance structures	core assembler in the apex of the net. Hierarchization of suppliers of sub-systems and components in different levels, according to the relevance of productive links, which assume a multidimensional character.
Forms of co-ordination	methods of production planning; protocols based on just-in-time principles; co-development of new components and sub-systems; management of modular architecture. Long-term contracts with incentive mechanisms to stimulate the increase of productivity-quality of components.
III - Technological Characteristics	
Characteristics of Informational Flows	continuous interchange of information about performance and quality of components and sub-systems. Specific learning mechanisms at the architectural level. Co-development of new components. Two-way informational flows. Sophisticated informational infra-structure (EDI).
Impact of Interactive Learning Mechanisms	improvement of existing components. Development of new components and sub-systems to be accommodated in the existent architecture. Development of variations of products with basis in the same architecture. Periodic redefinitions of modular architecture.
Innovative Efforts Performed	'programmed innovations' through product development projects based in the integration of new components and sub-systems in a modular architecture. Strong interactions with main suppliers to joint definition of design and to the development of new components.

Table 4 - Network Modus-operandi - Complex Products Networks

Dimensions	Characteristic
I - Technical Productive Characteristics	
Basic Characteristic	productive relationships associated with the generation of single-customised 'complex products'. Organisation in a temporary project basis, being co-ordinated by 'systems integrators' and involving a net of suppliers of components, sub-systems and software
Products' attributes	high cost; one-off or tailored batches; engineering intensive; complex interfaces; hierarchy of sub-systems; non-linear proprieties of architectures; very low tolerance margins.
Objective of arrangement	integration of components, subsystems and software in order to generated customised products that attend specific demands of sophisticated buyers in terms of performance, capacity and reliability
Technical-Productive Gains	integration of very different skills. Reduction of cost and lead-time of projects. Specialisation gains in the production of sub-systems. Increase of performance through the integration of hardware and software. Customisation gains through systems integration.
II - Inter-Organisational Characteristics	
Typical relations	relations established between firms that act as 'systems integrators' and a network of suppliers of sub-systems. Relations based in specific projects, with previous definition of tasks to be performed by network members. More direct involvement of users.
Governance structures	project-based and transitory character. Systems integrator firms responsible by the management of the project. Hierachisation in the function of the diversity of components and sub-systems that must be integrated at the project level. Virtual character after the conclusion of the project.
Forms of co-ordination	*ex-ante* co-ordination associated to project management techniques and parallel engineering implemented by systems integrators. Few large transaction based in incomplete contracts with negotiated prices. Intense use of information technologies and software techniques.
III - Technological Characteristics	
Characteristics of Informational Flows	intense involvement with users to define needs and customise the system. Interchange of information about sub-system proprieties that must become compatible. Informational flows associated to project management techniques. Sophisticated technical assistance.
Impact of Interactive Learning Mechanisms	customisation of product according to users needs. Development of systems integration competencies. Construction of 'markets' that can not be based in arms-length transactions. Consolidation of multi-firm alliances for innovation and production that can be mobilised in new projects.
Innovative Efforts Performed	project-basis character oriented to systems integration Strong user-producer involvement. Innovation paths agreed *ex-ante*. Non linear properties based in interdependent sub-systems. Integration of hardware and software according to users' needs.

Table 5 - Network Modus-operandi - Technology Based Networks

Dimensions	Characteristic
I - Technical Productive Characteristics	
Basic Characteristic	productive relationships related to the generation of high-tech products that require the integration of complementary assets and skills. Integration between technological and scientific spheres. Possibility of spatial organisation in 'technology poles'.
Products' attributes	high value; low volume; high-intensity in R&D efforts; associated to emergent markets; complex and tacit knowledge embodied; long development cycle; proprieties to be defined with basis in interactions with end-user activities.
Objective of arrangement	integration of competencies in different stages of the cycle R&D-production, reducing the lead-time of the development of new technologies. Acceleration of the process of technology transfer between high-tech firms and end-users sectors. 'Construction' of markets through inter-firm interaction.
Technical-Productive Gains	reduction of lead-time associated with the transition R&D-production. External economies in the provision of technological services. Specialisation gains associated to techno-scientific core competencies. Technological sophistication of products generated by end-users sectors.
II - Inter-Organisational Characteristics	
Typical relations	specifically related to a division of tasks in the cycle R&D production. Based on relations between technology based firms and other agents as a supplier (when they interact with a end-user sector of the technology) or as a buyer (when they interact with agents inserted in the scientific-technological infra-structure).
Governance structures	central role of technology-based firms. Integration of different stages of R&D process. 'Volatile' structures, that can change due to the acquisition of technology-based firms. Adaptations of structure to 'life cycle' model, with progressive centralisation of internal flows.
Forms of co-ordination	R&D projects co-ordinated by technology-based firms. Possibility of broader co-ordination through co-operative programmes with a public or semi-public character. Use of incomplete contracts, with pre-definition of appropiability conditions of innovations generated.
III - Technological Characteristics	
Characteristics of Informational Flows	feed-back loops between R&D stages associated with inter-personal and inter-teams relations. Informational flows related to the transmission of tacit knowledge. Informational flows between different cognitive backgrounds and knowledge fields. Relevance of bridge institutions.
Impact of Interactive Learning Mechanisms	reduction of costs and lead-time of R&D process. Integration of technological and scientific competencies. Definition of 'appropiability conditions'. Codification of tacit knowledge. Definition of language codes between different cognitive backgrounds.
Innovative Efforts Performed	interdisciplinary character, involving different stages of R&D cycle, with presence of feed-back loops (*chain linked model*). Relevance of basic research to generate new knowledge. Difficult to define *ex-ante* the results of R&D projects. Strong interconnections with technological and scientific infra-structure..

Bibliography

AOKI, M. 'Toward an Economic Model of the japanese Firm', Journal of Economic Literature, Vol. XXVIII, p 1-27, march, 1990

AXELSSON, B 'Network research - future issues', in: AXELSSON, B and EASTON, G. (eds) '*Industrial Networks: a new view of reality*', Routledge, London, 1993

BABA, Y. '*Systemic Innovation: its nature and how to benefit from it*', mimeo, SPRU- University of Sussex, april, 1988

BANDT, J. 'Économie Industrielle: un programme de recherche ouvert', *Revue d'Economie Industrielle*, n. 52, 2er trimestre, 1990

BAUDRY, B. 'Segmentation du marché du travail et segmentation du marché de la sous-traitance: une étude de la firme-réseaux', *Révue Économie Politique*, 104 (1), jan-fevr, 1994

BEIJE, P.R. and GROENEWEGEN, J. 'A Network Analysis of Markets', *Journal of Economic Issues*, vol. XXVI, no 1, march, 1992

BELLANDI, M. 'The incentives to decentralized industrial creativity in local systems of small firms', *Revue d'Economie Industrielle*, n. 59, ler trimestre, 1992

BEST, M. '*The New Competition*', Cambridge, Harvard University Press, 1990

BIANCHI, P. 'Galileo used tolive here. Touscany Hi Tech: the network and its poles', *R&D Management* 26, 3 pp 199-211, 1996

BIDAULT, F. 'Apprentissage et reseaux', *Economies et Societés - Série Dynamique technologique et organization*, W.1, no 5, 79-101, mai 1993

CAMAGNI, R. 'Local 'millieu', uncertainty and innovation networks: towards a new dynamic theory of economic space', in R, Camagni (ed), *Innovation Networks: Spatial Perspectives*. London and New York, Belhaven press, 1991

CARLSSON, B. 'Industrial Dynamics: a framework for analysis of industrial transformation', *Revue d'Economie Industrielle*, n. 61, 3er trimestre, 1992

CARLSSON, B. e STANKIEWICZ, R. 'On the nature, function and composition of technological systems'. *Journal of Evolutionary Economics*, no 1, 93-118, 1991

CHRISTENSEN, C. e ROSENBLOOM, R. 'Explaining the attacker's advantage: technological paradigms, organizational dynamics and the value network', *Research Policy*, 24, 233-257, 1995

CORIAT, B. 'The revitalization of mass production in the computer age', in: STORPER, M. e SCOTT, A. (eds) '*Pathways to industrial and regional development*', Routledge, 1992

CORIAT, B. 'Variety, routines an networks: the metamorphosis of fordist firms', *Industrial and Corporate Change*, Volume 4, no 1, 1995

DAVID, P.A. 'Some Standards for the Economics of Standardization in the Information Age', in: Dasgupta, P. and Stoneman, P. (eds) *Economic Policy and Technological Performance*, New York, Cambridge University press, 1987

DIJK, M.P. 'Flexible Specialization, The New Competition and industrial Districts', *Small Business Economics*, no 7, 15-27, 1995

DOSI, G. and KOGUT, B. 'National Specificities and the Context of Change: the Coevolution of Organization and Technology'. in: Kogut, B. (ed) *Country Competitiveness: Technology and the Organizing of Work*, Oxford University Press, 1993

DOSI, G. and MALERBA, F. 'Organizational Leraning and institutional Embeddedness', in: Dosi, G. and malerba, F. (eds) *Organisation and Strategy in the Evolution of Enterprise*, Elsevier Publishers, 1996

DYER, J. 'How Crysler Created an American Keiretsu', *Harvad Business Review*, p. 42-56, July-August, 1996

DYER, J. 'Specialized supplier networks as a source of competitive advantage: evidence from the auto industry', *Strategic Management Journal*, vol 17, 271-291, 1996

EASTON, G. 'Industrial networks: a review', in: AXELSSON, B and EASTON, G. (eds) '*Industrial Networks: a new view of reality*', Routledge, London, 1993

EASTON, G. and LUNDGREEN, A. 'Changes in industial networks as flow through nodes', in: AXELSSON, B and EASTON, G. (eds) '*Industrial Networks: a new view of reality*', Routledge, London, 1993

FORAY, D. 'The secrets of industry are in the air: industrial cooperation and the organizational dynamics of the innovative firm', *Research Policy*, no 20, 393-405, 1991

FORAY, D. e LUNDVALL, B.A. 'The knowledge-based economy: from the economics of knowledge to the learning economy', in: Employment and Growth in the Knowledge-based Economy', *OECD Documents*, 1996

GAROFOLI, G. 'Economic Development, Organization of Production and Territory', *Revue d'Economie Industrielle*, n. 64, 2er trimestre, 1993

GLASSMEIER, A. ‘Technological discontinuities and flexible production networks: the case of Switzerland and the world watch industry’, *Research Policy*, 20, 469-485, 1991

GRABHER, G. ‘Rediscovering the social in the economics of interfirm relations’, in: GRABHER, G. (ed) ‘*The embedded firm: on the socioeconomics of industrial networks*’, Routledge, London and New York, 1993

GRANDORI, A. e SODA, G. ‘Inter-firm Networks: Antecedents, Mechanisms and Forms’, *Organization Studies*, 16/2, 183-214, 1995

GRANOVETTER, M. ‘Economic action and social structure: the problem of embeddedness’, *American Journal of Sociology*, 91, 3 ,1985

HAKANSSON E JOHANSSON (1994), ‘The network as a governance structure: interfirm cooperation beyond markets and hierarchies’ in: GRABHER, G. (ed) ‘*The embedded firm: on the socioeconomics of industrial networks*’, Routledge, London and New York, 1993

HAKASSON, H. ‘*Corporate technological behaviour: cooperation and networks*’, Routledge, London and New York, 1989

HELPER, S. ‘An exit-voice analysis of supplier relations: the case of the US atomobile industry’, in: GRABHER, G. (ed) ‘*The embedded firm: on the socioeconomics of industrial networks*’, Routledge, London and New York, 1993

HENDERSON, R. and CLARK, K. ‘Architectural Innovation: the Reconfiguation of Existing Product Technologies and the failure of established Firms’, *Administrative Science Quartely*, 35, 9-30, 1990

HERRIGEL, G. B. ‘Power and the redefinition of industrial discrits: the case of Baden-Wurttenberg’, in: GRABHER, G. (ed) ‘*The embedded firm: on the socioeconomics of industrial networks*’, Routledge, London and New York, 1993

HOBDAY, M. ‘*Complex System vs. Mass Production: a New Innovation Agenda’*, mimeo, SPRU-Sussex, June, 1995

HOBDAY, M. ‘*Product complexity, innovation and industrial organisation*’, mimeo, SPRU-Sussex, February, 1997

HOLLINGSWORTH, R., SHMITTER, P. STREECK, W. (eds) ‘*Governing Capitalist Economies: performance and control of economic sectors*’, Oxford University Press, 1994

HUMPHREY, J. and SCHMITZ, H. ‘*Trust and economic development*’, Institute of Development Studies, *Discussion Paper 355*, august, 1996

IMAI, K. and BABA, Y. ‘Systemic Innovation and Cross-Border Networks’, paper prepared for the *International Seminar on the Contributions of Science and Technology to Economic Growth at OECD*, Paris, june, 1989

JARILLO, J. C. ‘On strategic networks’, *Strategic Management Journal*, vol9, 31-41, 1988

JESSOP, B. ‘Fordism and Post-Fordism: a Critical Reformulaation’, in: Storper, M. and Scott, A. (eds) ‘*Pathways to Industrialization and Regional Development*’, Routledge, London and new York, 1992

JOHANSON, J. and MATTSSON, L. ‘Interorganizational Relations in Industrial Systems: a Network Approach Compared with a Transactions Cost Approach’, *International Studies of Management and Organization*, 17, 3-24, 1987; also in *‘Markets, Hierarchies and Networks’*, Sage Publications, London, 1991

JOHNSON, B. and LUNDVALL, B.’The Learning Economy’, *Journal of Industry Studies*, Vol.1, no 2, 23-42. December, 1994

JOHNSON, B. and LUNDVALL, B. ‘Closing the institutional gap?’, *Revue d’Economie Industrielle*, no 59, 111-123, 1er trimestre, 1992

JOLY, P.B. and MANGEMATIN, V. ‘Les acteurs sont-ils solubles dans les reseaux?’, *Economies et Societées, Serié Dynamique technologique et organization*, w, no 2, p 17-50, septembre, 1995

KAPLINSKY, R. ‘Technique and system: the spread of japanese management techniques to developing countries’, *World Development*, vol.23, no 1, p 57-71, 1995

KARLSSON, C.and WESTIN, L. ‘Patterns of a Network Economy - an Introduction’, in: JOHANSSON, B., KARLSSON, C. , WESTIN, L. (eds) ‘*Patterns of a Network Economy*’, Springer-Verlag, 1994

KLINE, S.J. ‘A Numerical Index for the Complexity of Systems: the Concept and Some Implications’, Proceeding of 1990 Conference, Association for Computing Machinery on Managing Complexity and Modeling Reality, New York, ACM Press, 1991

LANGLOIS, R.e ROBERTSON, P. ‘Networks and innovation in a modular system: lessons from the microcomputer and stereo component industries’, *Research Policy*, vol. 21, 297-313, North-Holland, 1992

LAZERZON, M. ‘Factory or putting-out? Knitting networks in Modena’, in: GRABHER, G. (ed) ‘*The embedded firm: on the socioeconomics of industrial networks*’, Routledge, London and New York, 1993

LEONCINI, R., MAGGIONI, M.A. and MONTRESOR, S. 'Intersectoral innovation flows and national technological systems: network analysis for comparing Italy and German', *Research Policy*, 25, 415-430, 1996

LIKER, J.K., KAMATH, R.R., WASTI, S.N. e NAGAMACHI, M. 'Supplier involvment in automotive component design: are ther really large US Japan differences', *Research Policy*, 25, 59-89, 1996

LIPIETZ, A. and LEBORGNE, D. 'L'après-fordisme: idées fausses et questions ouvertes', *Problèmes Economiques*, no 2260, 13-24, 29 janvier 1992

LUNDGREEN, A. '*Technological Innovation and Network Evolution*', Routledge, 1995

LUNDVALL, B. 'Explainning interfirm cooperation and innovation: limits os the transaction-cost approach' in: GRABHER, G. (ed) '*The embedded firm: on the socioeconomics of industrial networks*', Routledge, London and New York, 1993

LUNDVALL, B. 'Innovation as an interactive process: from user-production interaction to the national system of innovation' in Dosi et alli, *'Technical Change and Economic Theory'*, Pinter Publishers, London, 1988

MAISSEU, A. 'Managing technological flows into corporate strategy', *International Journal of Technology Mangement*; Vol 10; no 1, 1995

MALERBA, F. and ORSENIGO, L. 'Technological Regimes and Firm Behaviour', *Industrial Corporate Change*, Volume 2, Number 1, 41-71, 1993

MARSHALL, A. '*Principles of Economy*', Macmillan, Londres, 1920

MILLER, R., HOBDAY, M., LEROUX-DEMOS AND OLLEROS, X. 'Innovation in Complex Systems Industries: the case of Flight Simulation', *Industrial and Corporate Change*, vol 4, no 2, pp 363-400, 1995

MUELLER, F. e LOVERIDGE, R.'The second industrial divide? The role of the large firm in the Baden-Wüttemberg', *Industrial and Corporate Change*, Volume 4, number 3, 1995

NELSON , R. and WINTER, S. *'An Evolutionary Theory of Economic Change'*, Cambridge, University Press,1982

NELSON, R. 'The Co-evolution of Technology, Industrial Structure and Supporting Institutions', *Industrial and Corporate Change*, volume, 3, number 1, 1994

NOORI, H. 'Economies of integration: a new manufacturing focus', *International Journal of Technology Management*, vol.5, no. 5, 577-587, 1990

PAVITT, K. 'Sectoral patterns of technical change: towards a taxonomy and a theory', *Research Policy*, vol. 13, North-Holland, 1984

PAVITT, K. 'What we know about the strategic management of technology', *California Management Review*, 17-26,spring,1990

PINE, B.J; VICTOR, B. and BOYNTON, A. 'Making Mass customization Work', *Harvard Business Review*, 108-119, September-October, 1993

PIORE, M. and SABEL, C. *The Second industrial Divide*, New York, Basic Books, 1984

POWELL, W.W. 'Neither market nor hierarchy: networs forms of organization', *Research in Organizational Behaviour*, 12, 295-336, 1990; also in *'Markets, Hierarchies and Networks'*, Sage Publications, London, 1991

PROVAN, K. 'Embeddedness, interdependence and Opportunism in organizational Supplier-Buyer Networks', *Journal of Mangement*, vol.19, no 4, 841-856, 1993

PYKE, P. and SENGENBERGER, W. 'Industrial districts and local economic regeneration: research and policy issues', in: P. Pyke and W. Sengenberger (eds) '*Industrial districts and local economic regeneration*', International Institute for Labour Studies, Geneva, 1992

RABELOTTI, R. 'Is there an 'industrial district model'? Footwear districts in Italy and Mexico compared', *World Development*, vol.23, no 1, p 29-41, 1995

ROTHWELL, R. 'Successful industrial innovation: critical factors for the 1990s', *R&D Management*, 22, 3, 1992

ROY, R. and POTTER, S. 'Managing engineering design in complex supply chains', *International Journal of Technology Management,* vol 12, no 4, 403-419, 1996

RYCROFT, R and KASH, D. 'Complex technology and community: implications for policy and social science', *Research Policy*, 23, 613-626, 1994

SAKO, M. '*Prices, Quality and Trust*', Cambridge: Cambridge University Press, 1992

SALAIS, R and STORPER, M. 'The four 'worlds' of contemporary industry', *Cambridge Journal of Economics*, 16, 169-193, 1992

SANCHEZ, R. and MAHONEY, J. 'Modularity, Flexibility and Knowledge Management in Production and Organisation Design', *Strategic Management Journal*, vol 17,Winter Special Issue, 63-76, 1996

SAXENIAN, A. 'Divergent patterns of business organization in Silicon Valley', in: STORPER, M. e SCOTT, A. (eds) '*Pathways to industrial and regional development*', Routledge, 1992

SAXENIAN, A. 'Regional networks and the resurgence of Silicon Valley', *California Management Review*, 89-112, Fall, 1990

SAXENIAN, A. 'The origins and dynamics of production networks in Silicon Valley', *Research Policy*, 20, 423-437, North-Holland, 1991

SCHMITZ, H. 'Collective Efficiency: growth path for small-scale industry', *The Journal of Development Studies*, vol.31, no 4, April, 1995

SCHMITZ, H. 'Small shoemakers and fordist giants: a tale of a supercluster', *World Development*, vol.23, no 1, p 9-28, 1995

SCHMITZ, H. 'Industrial districts: model and reality in Baden-Wurttemberg, Germany', in: P. Pyke and W. Sengenberger (eds) '*Industrial districts and local economic regeneration*', International Institute for Labour Studies, Geneva, 1992

SCHMITZ, H. and MUSYCK, B. 'Industrial districts in Europe: policy lessons for developing countries', *World Development*, vol.23, no 1, p 9-28, 1995

SCHMITZ, H. and NADAVI, K. '*Industrial clusters in less development countries: review of experiences and research agenda*', IDS Discussion Paper, University of Sussex, january, 1994

SEMLINGER, K 'Small firm and outsourcing as flexibility reservoirs of large firms' in: GRABHER, G. (ed) '*The embedded firm: on the socioeconomics of industrial networks*', Routledge, London and New York, 1993

SEMLINGER, K. 'Innovation, cooperation and strategic contracting', Paper prepared for the international colloquium on *'Management of Technology: Implications for Entreprise Management and Public Policy',* Paris, may, 1991

SENKER, J. and FAULKNER, W. 'Netwoks and tacit Knowledge in Innovation', *Economies et Societées*, Serié Dynamique technologique et organization, no 2, p 60-98, septembre, 1995

SINGH, K. 'The impact of technological complexity and interfirm cooperation on business survival', *Academy of Management Journal*, vol.40, no 2, 339-367, 1997

STORPER, M. and HARRISON, B. 'Flexibility, hierarchy and regional development: the changing structure of industrial production systems and their forms of governance in the 1990s', *Research Policy*, n.20, 407-422, 1991

TEUBAL M. and ZUSCOVITCH, E. 'Demand revealing and knowledge differentiation through network evolution' in: JOHANSSON, B., KARLSSON, C., WESTIN, L. (eds) '*Patterns of a Network Economy*', Springer-Verlag, 1994

TEUBAL, M., YINNON, T. and ZUSCOVITCH, E. 'Networks and market criation', *Research Policy*, n.20, 381-392, 1991

THOMAS, R. 'External techonology in industrial networks: relationship strategy and management', *Aseat Conference*, Umist, april, 1993

THOMPSON, G., FRANCES, J. , LEVACIC, R. e MITCHELL, J. *'Markets, Hierarchies and Networks'*, Sage Publications, London, 1991

TODTLING, F. 'Regional networks of high-technology firms - the case of the Greater Boston region', *Technovation*, 14(5), 323-343, 1994

WOODWARD, J. '*Management and technology*', 1958

ZUSCOVITCH, E. and COHEN, G. 'Network characteristics of technological learning: the case of the european space program', *Economic Innovation and New Tecnnolgy*, vol. 3, 139-160, 1994