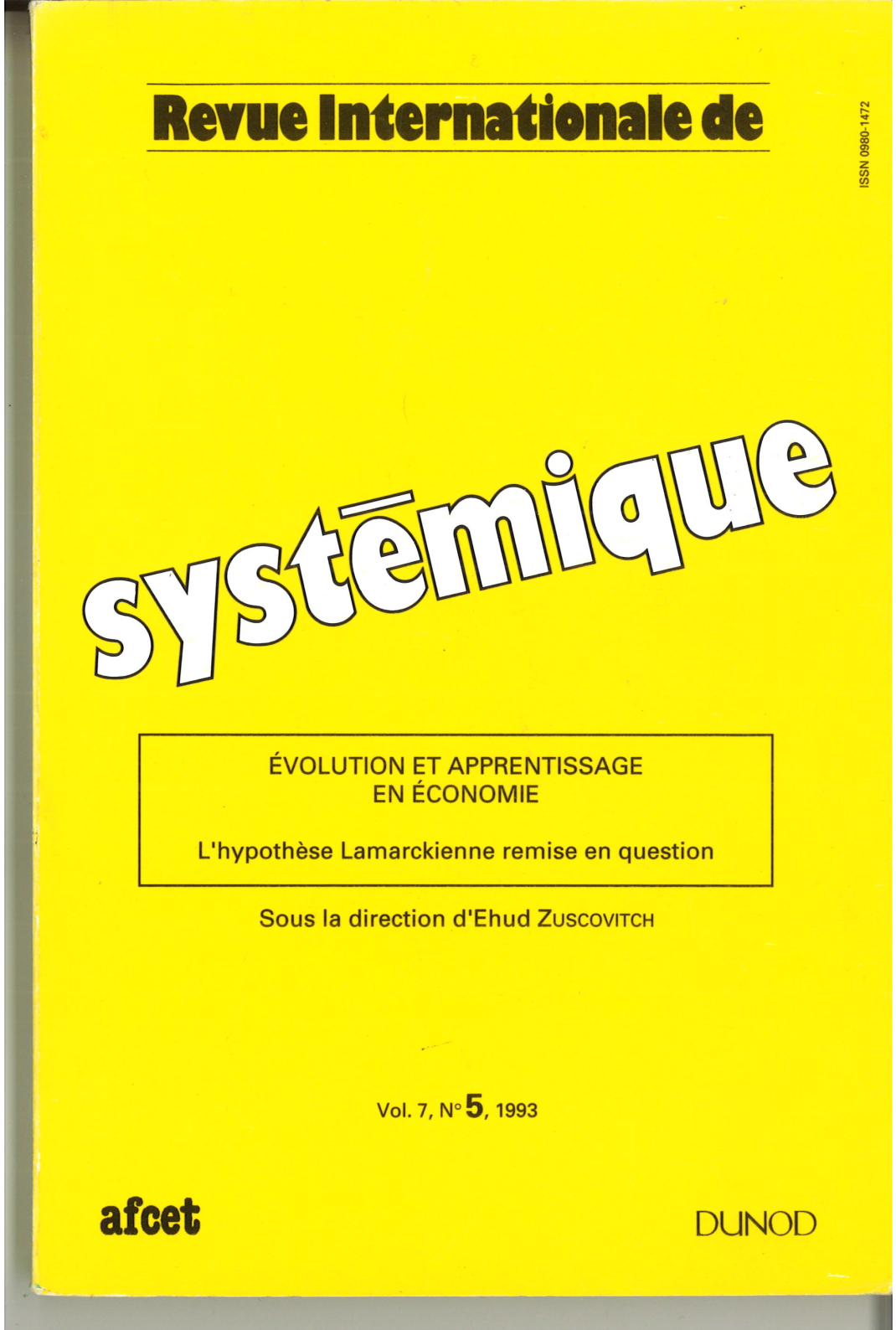

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COHERENCE, DIVERSITY OF ASSETS AND NETWORKS: TOWARDS AN EVOLUTIONARY APPROACH

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Abstract
The concept of network is nowadays taking a growing importance in the academic literature as well as in the strategic behaviour of firms. The purpose of this paper is to investigate why there is a growing interest for networks, what is the theoretical root of the concept and how the phenomena of learning and the coherence and diversity of assets are related to it. To do so we shall make use of the theory of evolutionary economics. Networks appear then as a specific organisational form, for the evolutionary process undergoing in modern manufacturing systems.

Résumé
Le concept de réseau remplit un rôle croissant aussi bien dans les travaux des chercheurs que dans le comportement stratégique des firmes. L'objectif de cet article est de clarifier cette tendance en proposant au concept un fondement analytique et en le situant par rapport aux phénomènes d'apprentissage de cohérence et de la diversité d'actifs. Nous utiliserons pour ce faire la théorie évolutionniste. Le réseau apparaît alors comme une forme organisationnelle spécifique au processus d'évolution du système productif moderne.

The concept of network is nowadays taking a growing place in the academic literature as well as in the strategic behaviors of firms. Considerable efforts have been recently realized to clarify the concept and to set up precise typologies of different network forms (Thorelli, 1984; Powell, 1988; Grandori, 1991). However, many theoretical and practical issues remain at stake: this

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article will precisely focus on some of these aspects by investigating three basic questions concerning networks:

– How can we explain on theoretical grounds, the growing interest for the concept of network? To answer this question, we shall emphasize the evolution of manufacturing systems towards growing levels of complexity, with an actual situation characterized by fundamental unpredictability and disturbed information. In this context, an efficient way for organizations (like firms) to maintain their viability is to function within a networking scheme.

– What is the theoretical root of the concept of network? Is network a simple intermediate form between pure hierarchy and market? Is it a specific theoretical category from which other (firms, coalitions, etc.) can be deduced? Answers to these questions are not only of theoretical interest. They could help to understand strategies and evolution by networks towards different organizational forms.

– How the phenomena of learning and the coherence of diversity of assets are related to the concept of network? From this question arise not only the understanding of the efficiency of networks, but also the understanding of the dynamic of organizations and cooperations in industry.

To be able to give some answer to these three questions, we have to use concepts developped by the theory of evolutionary economics. It is particularly the case for the analysis of the manufacturing systems. Growing complexity implies new characteristics of the systems to survive. In particular, learning processes mean creation of new competences as well as destruction of existing capabilities. Networks appear then as a specific organisational form for this evolutionary process.

I. THE EVOLUTION OF MANUFACTURING SYSTEMS AND THE GROWING INTEREST FOR NETWORKS

Since the beginning of the industrial era, manufacturing systems have evolved constantly towards growing levels of complexity. If one admits that a manufacturing system at a given moment is characterized by a certain type of organization suited for a certain type of economic environment (as defined by the state of demand, of competition and of technology), one can distinguish three successive stages in the evolution of manufacturing models: the "standardization" model, the "variety" model and the "reactivity" model. In the following explanation of these three successive models, two essential phenomena arise: on the one hand the growing importance of the notion

of flexibility, a multidimensional concept which progressively becomes one of the major objectives of organizations as they experience higher levels of complexity; and on the other hand the deep break which appears between the variety and the reactivity models, due to the radical changes in the nature of information and in the way the information flows between the firm and its environment. For before the reactivity model, the information system could be considered as stable and repetitive; but with the reactivity system, it becomes mainly disturbed. Disturbed information is characterised by great unpredictability, due mainly to the interdependance of economic agents and their unpredictable strategies (competitors and consumers). As will be shown, this very last characteristic causes the organization of the firm to be thought out again from the perspective of a growing integration, from which the interest of network can be understood.

I.1. The standardization and variety models

The characteristics of the standardization model are well known. This model, and its most sophisticated expression, the so-called "taylorian-fordian" model, evokes mass production, the creation of products with a long life-cycle and sequential manufacturing processes with a clear separation between functional and production departments. This system proves particularly efficient when the firm has to face an environment characterized by a homogeneous demand and a regular growth. When applied to technology this model is characterized by a growing mechanization of equipment meant for mass production. This logic is actually totally compatible with the introduction of the first automation (transfer machines and equipment). As for the organization of workshops, it relies on sections of conventional machines set in banks. It is to be noted that this structure can be broken up into successive pre-determined manufacturing phases. This structure is then given and is **independent of the state of the environment** (especially as far as demand is concerned). This last remark applies both to the decision-making process within the firm in which decisions are taken centrally and to the pyramidal structure. As for the management and decision-making methods, they have been built progressively on the basis of the "taylorian-fordian" model, be it to manage the production (methods of operations research, stock and inventory management, etc.), to prepare financial decisions (classical investment criteria) or to manage personnel (through the system of job classification), etc.

A second model can be characterized by the efforts made as early as the 1920s in particular by General Motors to diversify its production through

concentration by means of technical, economic and financial integration, the aim being to reach a size which enabled it to mobilize the financial resources to be allocated to developing new products: this model can be called the **(planned) variety** model. It is the paradigm of monopolistic competition *à la* Chamberlain. The progressive transition from a homogeneous demand to a varied, uncertain one with specific requirements with regard to the quality of the products seems to be an irreversible trend of the economic environment. The users not only require personalised characteristics but they also increasingly demand that "services" be more included in the products (short delivery time, after-sales service, maintenance, reliability, etc.). This latter requirement has of course become one of the decisive factors of competition between firms. On the other hand the technological development of CNC machines and machining cells, which make it possible to perform different types of operations while reducing the difficulties connected with the reconfiguration of lines, has considerably eased the transition towards a variety model.

All the characteristics which have been mentioned above show considerable differences between the variety and the standardization models. However the two models always coincide on one fundamental point, i.e. that in neither model the logic of **the independence between the firm's organization and the state of the environment** is questioned. This logic remains valid because the information flow coming from the environment can be considered as **stable, foreseeable and repetitive**, thus allowing decisions to be planned. Moreover the variety model provides the same separation between administrative and production departments.

In both models the nature of information (stable and foreseeable) allows the organization to be hierarchical and split up since coordination between the various services, departments or functions is routine and can be pre-determined: it is a procedure which from one period to the other recurs strictly identically.

I.2. The reactivity model

From the mid-60s onwards, competition between firms, which within the standardization model had concentrated previously on quantity-price parameters and later within the variety model on product differentiation, has slowly evolved towards the need for **reactivity**. In a way the dying out of the former standards of competition has made room for a totally new type of competition between firms.

The notion of reactivity implies that the firm is able to reorganize quickly its production resources and is capable of rapidly satisfying consumers' requirements (in the shortest possible delivery time for instance) (cf. Coriat, 1990). The time dimension of the reactivity model is pre-dominant. Time has been always an important factor of productivity as already mentioned by Chandler (1977). "It was not the size of a manufacturing establishment in terms of number of workers and the amount and the value of productive equipment but velocity of throughput and the resulting increase in volume that permitted economies that lowered costs and increased output per workers and per machine" (Chandler, 1977, p. 244). Recent works along this line permit to distinguish the scale and the speed dimensions to technical and organizational evolution of the manufacturing systems (Matthews, 1990). However, in the reactivity model, time is the main source of competitive advantage and velocity becomes the measurement of performance of firms (Stalk, 1988). In fact, by "reactivity", we mean "re-active" decisions, taking in account the environmental changes as well as "pro-active" actions which determine, at least partially, the context and the environmental conditions in which the stategies take place (see Amendola-Bruno, 1990).

Consequently, this trend towards a greater reactivity means in fact a deep break in the manufacturing processes. For it introduces the **need for a strict dependence between the organization of the firm and the variations of the environment**. This is a radical break from previous systems because the firm, having to face an environment which can be characterized by a constantly varying demand and a tough competition on the time-dimension, cannot take its organization for granted for ever: this evolutionary nature of the environment makes it necessary for each component of the firm to have a flexible attitude towards information. Consequently,

– the nature of the flexibilities implemented in the manufacturing systems becomes essential for the competitiveness of the firms;

– the question of the global coherence of the firm has to be put differently: stable interaction procedures between the various components are not sufficient any more. In order to be able to overcome this evolution of the production systems, integration becomes a strategic element of their competition in a disturbed environment.

From these reasons, comes the rationale for thinking in terms of network as a device to coordinate resources and behaviors in a disturbed environment. However, a critical issue can be pinpointed when considering this rationale: can the concept of network be applied in the same way for approaching on one side the behavior and evolution of the firm itself (by focusing on the

internal network organization of the firm that integrates different bodies of knowledge) and on the other side the behavior and the evolution of inter-firm cooperation? Can we use the same theoretical category to investigate micro-organizations and meso (and even macro) organizations? And if not, what are the differences in the ways the concept of network is used in different contexts? What is the meaning of the notion of frontier or boundary of the firm in the new model of manufacturing process?

The hypothesis we shall develop in this article is that if by many aspects there are some common features between "internal" (firm) and "external" (inter-firm) networks, there are also strong differences in the ways activities are integrated, objectives are determined, appropriability is defined, horizons of time are envisaged, confidence is reached. At the level of the firm, an internal coherence is searched in order to obtain a dynamic (passive or reactive) flexibility. At the inter-firm level, the network cooperation is set-up to create positive externalities allowing individual firms to reach some control (achieve flexibility) of their environment.

At this point of our development, we need to be more specific about the nature of flexibilities that, according to our hypothesis, determines the choice of the form of networks.

I.3. Flexibilities and integration processes

The evolution of the manufacturing systems from the standardization model to the variety model and then the reactivity model shows the growing ability of firms to function at increasing levels of complexity. Nevertheless the logic of this evolution as well as the driving forces behind these dynamics are not always obvious. Our **basic hypothesis** is that, on the one hand, the quest for flexibility is at the root of the dynamic evolution of the manufacturing systems, but that on the other hand this evolution has been only made possible because integration processes have ensured the economic viability of the new organizational forms being experienced (Cohendet-Llerena, 1987-1990).

The capability of a system (or an organization) to adapt itself to its environment could be a first approximative and general definition of "flexibility". And the so-called "search for increased flexibility" would then be most of the time the search for an **appropriate** flexibility, pertinent to a particular environment. In such a general setting, it is however possible to differentiate two types of environment:

– risky ones, where the changes and the evolutions are known, at least, in probabilistic terms;

– uncertain ones, where *a priori* probabilities don't exist or at least where learning processes are necessary to discover the characteristics of the environment.

In the former case, "static" flexibilities are needed, "dynamic" ones, in the latter.

By "static" flexibilities, we intend situations where, at each period, the decision-makers or the organizations have a complete set of "acts", pertinent to each possible state of the nature. Excess capacities, stocks of final products or simultaneous supply of several products are flexibilities of this type. Likewise, rescue equipments or equipments in parallel are means to cope with risks. In these cases, the classical dilemma between productivity or profitability and flexibility becomes a marked feature.

By "dynamic" flexibilities, we mean the capacity of a system to adapt continously through time to the evolution of its environment. In disturbed environment, the firm is not able to maintain simultaneously of a complete set of responses, mainly because of a lack of information. It has to start a learning process and to create appropriate solutions to continously renewed circumstances. Responsiveness becomes the most important criterion of business performance. One way to reach higher degree of dynamic flexibility is to "control" the environment itself by creating new states of the world, dictating the terms of competition through innovations for example.

To distinguish between two types of flexibilities enlights the analytical as well as the empirical problems posed by the search for flexibility in manufacturing systems (decision theory and theory of the firm: Jones-Ostroy, 1984; Llerena, 1985; Cohendet-Llerena, 1987, 1989; Carlsson, 1989; industrials dynamics: Klein, 1988; Cohen-Zysman, 1987; Amendola-Gaffard, 1988). In particular, it is then possible to understand the implications of flexibilities in terms of decision evaluation and industrial organization. Moreover, we remark that, even so different types of flexibilities exist simultaneously in a given industrial model, dynamic flexibility is predominant in the reactivity model.

The nature of the flexibilities which characterize a given model determines the level of complexity of the manufacturing system. The reactivity model implies a higher level than the variety of the standardization model. Moreover, it is an established fact that the complexity of the environment itself and in particular of the demand is also growing. More precisely, an increasing variety of products and services is offered to the consumer. The increasing complexity due to the search for flexibility and to the variety of products and services implies an increased quantity of information required in the

production processes, and more generally implies higher costs of production (Saviotti, 1988). The viability of such an economic development needs some counter-balancing phenomena: the integration processes. These integration processes are organizational as well as technological and are specific to an industrial regime and to its particular performance criteria. Table 1 gives some examples of such integration processes.

Table 1. Integration processes: some examples and characteristics.

Type of Integration	Nature of integration	Main importance Criterion	Model of Reference
Homogeneous machine-tools banks	Space integration	Economies of scale	Standardization
Reduction of production steps	Technological integration	Economies of production factors	All models
Delayed differentiation	Technological + Organizational	Increased down-streamed variety	Variety
Group technology	Technological integration	Increased down-streamed variety	Variety
Just in time	Organizational integration	Shorter lead time	Reactivity
Local Area Network (L.A.N.)	Technological + Organizational integration	Shorter lead time	Reactivity

As Saviotti (1988) shows, division of labor or hierarchical organization are examples of organizational principles which can decrease the information needed to monitor a manufacturing system. In a historical perspective, Lazonich (1990) analyses how organizational integrations characterize the transformation in capitalist organization. More generally, each model (standardization, variety, reactivity), specific to a particular environment, needs not only some degree of a particular type of flexibility (static for the standardization and variety models, dynamic for the reactivity one), but also to undergo some integration processes, to assure its viability.

II. INTERNAL INTEGRATION AS A STRATEGIC CHOICE IN THE REACTIVITY MODEL

Our purpose is now to explain more precisely the changes being observed in the so-called reactivity model. The nature of the model is an incentive to look at the organization of the firm from a different perspective. In order to stress this point and to analyse the precise nature and the relevance of an integration policy within this context, it is necessary to come back first to the major characteristic of the new production model: the need to function within a regime of disturbed information, which means in particular that the firm has to make some decisions which cannot be planned.

II.1. Some consequences of a regime of disturbed information

To take into account growing new information means that the decision-maker cannot any more evaluate his environment through an objective assessment of phenomena, but through a subjective one. The decision-maker is thus moving from a substantive rationality towards a "procedural" rationality (Simon, 1982).

The logic of decisions has therefore changed, as its field of investigation has become explicitely limited. The complexity of the environment and the existence of an irreducible uncertainty (a consequence of the nature of competition) restrict the scope of possibilities envisaged by the decision-maker. These limitations concern both the extent of the potentialities to be taken into account and the calculation of the benefits to be expected, i.e. their mode of assessment.

Once the principle of a limited rationality is accepted, the temporal and hierarchical horizons of the decision-makers and of the organizations are of prime importance. Indeed the field of investigation concerned by the search of solutions depends on these horizons. If, within the organization, the structure is considered as a variable independent of a quasi-certain environment, it may seem reasonable to assume that the rationality is perfect (or substantive). If such a rationality is assumed at each possible level of aggregation, coherence between the various levels can also legitimately be assumed (such a coherence plays an essential role). On the other hand, when an organization is in osmose with its environment, and when the decision process is based on a limited rationality, this coherence is constrained by the procedural character of the underlying rationality. The problem of coherence has then to be put in a totally different way. In this case it is necessary to define coherent local

procedures for looking for solutions, in connection with a global procedure and not at all in connection with some global objective. To put it simply, it would be necessary in this case to break a global procedure into local "sub-routines", which would take into account the different fields of investigation of the solutions attached to each level of the organization. This phenomenon strongly implies limiting the consequences of this lack of internal coherence.

The "bounded" rationality can be in fact viewed as one of the main phenomena explaining "economic organization". As Egidi (1989) argues, in games where the players face a complex situation with incomplete knowledge, surprise and incoherent expectations, some routines appear. These routines can be defined as a way of decomposing the initial problem in more simple sub-problems (objectively or subjectively) and for which there are some already existing sub-routines or even solutions. In a game like chess, the search is not a search in the set of solutions but in a set of sub-problems. But, contrary to the solutions, there are no pre-order between sub-problems, and there is no pre-established order in the sequence of solving them. An organization is a way to decentralize the routines in "sub-routines", linked together by parameters.

The problem posed by the reactivity model is the need to generate new routines and/or the change of the parameters. One of the solutions seems to be a better integration, i.e. to reduce the number of hierarchical levels within the firm and to integrate functions. To put it blunty, it means weakening the hierarchical structure of firms. This statement indicates a possible research path but says nothing about one of the questions which then becomes a focus point: how can the coherence between the different actors of the decision-making process be ensured? On this specific point one could make the assumption that, although it is useful to reduce the impact of this lack (by enlarging the field of investigation), internal coherence, in the narrow sense of substantive rationality, is not at all necessary. Divergences and conflicts will indeed be the driving force behind a negotiation process between the various actors and will be beneficial for carrying out a short and efficient learning process. This quest for a "consensus" or a "compromise" presents a pedagogical aspect not to be neglected when trying to understand how a decision-making process within a context of limited rationality can evolve in a proper way (see March, 1988).

These remarks have much in common with Favereau's (1989) who considers that "a hierarchical organization is no stable structure in empirical social systems". In fact a hierarchical organization is made of a decomposable structure, which means that it can be subdivided into sub-parts which are

connected through a causality link. If the interrelations between the members of the organization are represented on a matrix, it will be a triangular matrix of the following type:

$$\begin{matrix} a_1 & a_2 \\ 0 & a_3 \end{matrix}$$

Such an organization has a "natural" tendency to evolve towards a perfectly decomposable structure, in which the sub-parts become autonomous, totally independent of the environment and the global organization (a_2=0, the matrix becomes diagonal). This structure then looses the advantages associated with the decomposable structure as there is no flexible coordination between the sub-systems. One of the reasons of this autonomization is the growing number of restrictive rules, going beyond the rules strictly necessary ("constitutive") for the existence of the organization. The main consequence of this excess of restrictive rules is a growing independence of the sub-system with regard to the system as a whole and of the system with regard to its environment. The development of an internal labour market is a symptomatic case of this evolution (however the autonomization may prove to be advantageous given some configurations of the environment: cf. Simon (1951-1982), in the case of the employment contract). This autonomization is being reinforced by the existence of a "general trend among a human group to become autonomous with regard to the outside world, by getting organised according to internal considerations and motivations" (Favereau, 1989). The question arises then of the evolution of the system towards a new decomposable structure, or even non-decomposable, where organic links exist "again" between the sub-systems; these links could then partly ensure the coordination of the whole system and offer an opportunity to overcome the inertia inherent in perfectly decomposable systems. The creation of "quality circles", the emphasis put on the need to integrate functions within the firm, etc. partake of the evolution towards a "less decomposable" system of the firm.

II.2. Inter-firm network as a strategical external choice in the reactivity model

Up to now, we focus on the passive adaptation of the firm to an uncontrolled environment. Moreover, firms can try to control to a certain extend their environment, in order to develop and imagine new creative productive options, and be in a position to sell them in an organized market. This supposes strong interactions with the environment of the firm, to share with others sunk costs of research, nichs of development, setting up of

new productive options, development of new processes, exploitation and development of new markets. In this context of (active) dynamic flexibility one of the means for firms to achieve their objectives is to set up inter-firm networks. These types of coordination between firms embody a large range of different forms of organization (see A. Grandori, 1991): joint ventures, cross partnerships, consortia, relational contracting, industrial districts, associations, cartels, technological poles, scientific and commercial parks, etc. A lot of these forms of coordination are due to the fact that in an information-intensive and disturbed production system with a multiplicity of micromarkets with particular specifications for smaller production runs, there is a growing number of bodies of knowledge that one has to master and the only possible access to such a diversty is through cooperation with other producers and users of the products. The ability to have access to the know-how of firms in connected areas increases the value of all the firms involved in the network, provided thet their mutual degree of confidence is strong enough. Any way, at this point a clear understanding of the strategical issues at stake supposes to asses the theoretical meaning of the concept of network.

II.3. The theoretical meaning of the concept of network

It is often admitted in the academic literature that a network is an intermediate form between market and hierarchy, or represents a mixed form of "quasi-integration" (Blois, 1972; Mariti & Smiley, 1983). In such a context, network is nothing but the province of these two pure categories of economic coordinating modes. Moreover, most of these visions consider a network as an unstable form that should naturally evolve towards one of the pure coodination modes. The fact that market on one side, and hierarchy on the other side constitute the two refering poles of any theoretical approach implies that we are still thinking in the Williamsonian context of transaction cost economics ("which has added the reduction of governance costs to that of production costs in the explanation of networks' relative success". A. Grandori, *op. cit.*). This supposes that economic units can develop their mutual interactions through only two modalities: through hierarchical relations or through commercial (market) transactions. According to the context, economic units proceed to substitutions between these forms of modalities, and in the case of imperfect information a network type of intermediate form can be attained.

We suppose another theoretical vision of network that denies the idea that network is an intermediate category between market and hierarchy: we

assume that economic units are interacting according to three basic modalities: hierarchical relations, commercial transactions, and relations of confidence (M. Callon, 1991). Moreover, we do not assume that the modalities are mutually exclusive, which means that there could be any overlapping of the three different types of basic relations. There is no necesseraly a substitution between commercial transactions, confidence and hierarchy. Through this hypothesis, network is not an intermediate concept. It is according to the intensity of given relationships between economic units the standard form of interaction between these units; markets and pure hierarchies being the extreme forms of the spectrum.

However, even at the vicinity of these extreme forms the notion of network is to be considered. For exemple, when market forms are dominant, i.e. when commercial transactions represent the dominant and efficient mode of interaction between economic units, there is still a need to think in terms of network: a defined market supposes the existence of networks, of relations and conventions between agents to be able to describe goods, to define the conditions of exchange, to set up the set of contractual relationships in order for the market to function. On the other extreme, when hierarchy is the dominant form, there is always a need to describe the hierarchical forms at stake through the concept of (hierarchical) network. One would speak in terms of (hierarchical) network of subcontractors, (hierarchical) network of distribution, etc.

The above representation of the concept of network avoids the classical way offered by markets or hierarchy for dealing with the negociations between economic units. For the market or for the hierarchy any negociation is bilateral, or will end with a bilateral contract between two economic units (eventually certified by an external observer who is not involved in the negociation). From these bilateral negociation emerge for instance many phenomena of asymetry of information that introduce biais in the relationships between agents. These phenomena are sources of negative externalities. In the context of a network, where the belonging to a defined network involves by definition multilateral negotiation between members of the network, such phenomena as asymetries of information are naturally limited. If it is possible to cheat in a relation restricted to two units, it is certainly more difficult to do it in a relation which implies more than two members. Reputation effects for instance are at stake and play a regulating role limiting the external negative effects. There are formations of routines within the network, to regulate the confidence of the different members of the network (these also define a "price of entry" in the network). Such agreements, reciprocity

principals are established to ensure incentive compatibility among the agents, and favour positive externalities (spillovers, for instance between the agents). Thus confidence appears to be the critical element of the definition of network.

These fundamental principles being precised, it is now possible to adress the key question concerning networks: How can they offer a coherent framework to integrate diverse learning processes, either at the level of the firm, or at the level of the inter-firm cooperation, with the respective specificities that have been discussed above. We shall in this article mostly concentrate on the case of learning within the firm.

III. COHERENCE, COMMON KNOWLEDGE AND LEARNING

Since the fundamental break between the previous manifacturing models and the new reactivity model results from the changing nature of information (from "stable" to "disturbed" information), it can logically be deduced that the new organization to be conceived must strongly reflect this change in the nature of information. To be more specific, the information in the manufacturing models with stable information was structured around the material flow following a sequential principle, and a decision- making system corresponding to an unchanging hierarchy, since each decision, could be "planned" in advance. Such models do not give way to local, useless, disturbing initiatives, and have no interest either for local learning processes since everything can be planned globally and then decentralised.

In the case of a regime of disturbed information it is not possible any more to program decisions globally since there is no sufficiently repetitive information support to base these decisions on. The intensity and the nature of the material flow become strongly uncertain. The firm must therefore be structured in such a way as to ensure the most efficient attitude faced with a flow of uncertain information. In this context our assumption is that **the introduction of local learning processes is the most adequate organizational solution to make the organization viable**. This working assumption raises two main questions: how to define these "local learning processes"? how to "integrate" all these processes into a coherent network?

III.1. Problems related to coherent local learning processes

The difficulties to put forth a learning process (local and organizational) have been explicited by Holland *et al.* (1986) (see also Cohen (1987), Marengo (1992)):

State classification problems: creating new routines and/or modifying their using conditions require to identify and classify the states of the world. Learning is not reduced to a mere information gathering, but depends on prior representations held by the agents. These representations allow them to structure their environment and to take decisions. Attention will be given to what is happening in the environment.

Performance evaluation problems: to learn new rules and routines, agents will have to evaluate their performances. The evaluation procedures used determine their learning trajectories. It will be important to know if what is happening is profitable or not.

Credit allocation problems between rules: the evolution of the set of available routines will depend on the evaluation of their relative utilities. In a given situation, it will be important to assess which rule is the most appropriate. The focus will be on finding the most satisfactory rule.

At the production team level the three learning conditions above concern essentially the following characteristics:

- ability to identify the problem;
- ability to assimilate the external information, to compute it, to compare this information with previous experiences in order to work out a decision;
- ability to turn the signal received into a production (material or immaterial);
- ability to prepare the decision to manufacture;
- ability to control the production and guarantee the maintenance of the equipments;
- ability to take stock of what has been produced and to record the information;
- ability to identify and communicate with other elements of the firm concerned by the production at stake;
- ability to forward the information on manufacturing to other elements of the manufacturing system.

Moreover, organizational learning requires the coordination of different local learning processes. This specific condition to organizational learning gives rise to additional complications due to:

- diversity and spatial distribution of representations;
- diversity and spatial distribution of competences and information processing capacities;
- diversity of preferences and objectives;

– the influence of preferences on the evolution of representations and competences and *vice versa*.

The complexity to ensure an organizational learning has also been stressed in a different setting by March and Olsen (1975) who question the simple and complete learning cycle characterized by the following steps:

Individual action –> organizational action –> reaction of the environment –> individual convictions –> individual action –>...

According to them, this complete learning cycle is based on several unrealistic assumptions such as the lack of errors in the learning process or the complete rationality of learning agents. They propose an incomplete cycle based upon:

– learning constrained by the position held in the firm or by the firm;

– superstitious learning;

– non-diffused learning;

– environmental ambiguity.

Milgrom and Roberts (1990) paper on the analysis of complementarities among groups of activities or strategies of the firms can also cast some new light on learning problems in networks. They point out an awkward consequence of the economic analysis of complementary relations which introduce non-convexities and write: "these non convexities explain why successful adoption of modern manufacturing methods may not be a marginal decision". In fact, we will no more be able to find the optimal network solution through small local changes independent of each other. Exploiting such complementarities will call for systemic and systematic changes in the strategies and decisions of the firms in the network and a quick inter-firm cooperation.

These non-convexities set therefore a problem of incremental learning: the drastic changes implied by complementarities will generate important instability and adaptation or transition costs. Within this context, the development of local learning capacities cannot constitute a sufficient condition for network learning. Nevertheless, local capacities are a necessary condition to put forth a certain dynamics within the firm. The exploitation of this dynamic requires to constitute common reference points (focal points) for all members, which must guide these dynamics and adapt to it. These references or common knowledge are crucial to master the complementarities mentioned above and ensure learning at the network level. Integration can thus be a crucial factor in reducing adaptation and instability costs.

Integration within the firm can be a powerful tool to resolve, at least partially, some of the difficulties in generating organizational learning. In order to ensure an internal consistency, it seems important to create in the firm a common knowledge base (rules, codes, language) (Crémer, 1990) adapted to the information processing capacities and specific competences of the members. However diversity is also a main source of learning in the firm, provided that one can exploit it. In order to preserve such a diversity a sufficient level of autonomy must be awarded to the different sub-systems of a hierarchical organization. The main point is then to find a trade-off between decentralisation/centralisation and exploration/exploitation (March, 1990) allowing, on the one hand, an efficient use of the common knowledge existing in the firm, in order to ensure cooperation and coordination among different sub-systems, and on the other, to encourage innovation, risk taking and the search for new opportunities.

We can distinguish within the firm two types of structural integration: hierarchical and horizontal. The hierarchical integration consists in:

– reducing the number of hierarchical levels;

– intensifying the interactions between manufacturing shops and R&D, Marketing, Planning, etc.;

– broadening the operational competences towards quality control and maintenance competences;

– integrating the operational and coordination competences.

The hierarchy can also provide for a stable framework (production plans) through which different units will be able to interact. This integrative role of hierarchy consists in imposing objectives, centralizing information, developing and diffusing execution standards, rules on which the sub-systems will rely.

Horizontal integration could consist in:

– practising just-in-time (the use of kanban as a means of coordination and mutual control);

– implementing production teams;

– rotation of workers between shops;

– broadening the operational tasks;

– constituting common data bases.

The models of organizational architecture (Camacho-Persky, 1988; Camacho, 1991; Sah-Stiglitz, 1986: Ionnides, 1987) are of little use for our problem, because they disregard the learning effects. We will have to

look for more complex models of organization and organizational learning (Aoki, 1986, 1988, 1990; March, 1988; Marengo, 1990, 1992).

Aoki lays particular emphasis on the economic importance of information and tacit knowledge available in the production shops and clarifies the necessary conditions to generate an informational rent through horizontal integration. He compares the relative efficiency of two coordination modes, i.e. two ways to adapt to environmental changes (*a priori* and *ad hoc* adaptation). The main difference between these structures lies in their exploitation mode of *a posteriori* information.

The hierarchical structure is characterized in his model by a perfect knowledge of the technological possibilities by the Planning Office, an imperfect perception of production hazards (limited rationality) and a delay in the implementation of prescribed solutions (incentive problems and quality of the hierarchical structure).

The horizontal structure is essentialy characterized by a direct coordination among semi-autonomous shops, a localized and imperfect knowledge of the production process and a local learning of the optimal solution.

According to Aoki's analytical model, the relative informational efficiency of these two modes of coordination depends on the following parameters:

– the learning rate and the initial level of qualification of employees in the shops;

– the degree of imperfection of horizontal coordination;

– the imprecision rate in the perception of the hazards by the Planning Office;

– the obsolescence rate of technology;

– the quality of vertical information flows (delay, bias);

– the initial ignorance of events (variance) and volatility of the environment;

– the degree of competition.

Aoki's analysis concerning short term decisions stresses the importance of a partial hierarchical decentralisation and the necessity of a horizontal integration so as to facilitate the exchange of locally developed know-hows. As he shows the prerequisites for the functioning of such an integrated structure involve not only a technical dimension (information systems, shared data bases, expert systems, etc.) but mainly qualification and more precisely the learning and adaptation capabilities of human resources.

However, a criticism can be formulated towards his approach: if he centers his analysis mainly on the efficiency of information flows and the physical coordination, the question of the efficiency of knowledge flows and the

consistency of local learning processes is neglected as is the evolution of organizational knowledge. If importance is given to tacit know- how and what is locally learned, the necessity to convert them into objective knowledge, formal rules and standards through hierarchical participation is not discussed.

The analysis of coordination among local learning processes supposes that we focus our attention on the heterogeneity of learning rates in different sub-systems. As Lounamaa & March (1987) point out, when information is disturbed by noises, the performance of the organization is increased with a slower rate of adaptation and improves organizational learning: "the basic problem with fast learning rates is that false lessons are learned rapidly as well as true lessons". Generally, fast learning rates imply bad decisions caused by representation errors and a sub-optimal distribution of competences. The career development strategies and the rotation of employees among shops are closely related to the appropriate rate of learning to be practised in the firm (promotion speed, rotation speed). Such strategies should not only be considered as an opportunity for the maximization of individual interests, but should also take into consideration the structural and production characteristics of the firm so as to develop the appropriate competences (Prendergast, 1992). This issue is also related to the trade-off between cooperation and competition among firms in the network.

Similarly, the relative importance of common knowledge for the coordination of different economic activities is discussed by Crémer (1990). He compares the effect on the performance of the firm of two types of knowledge: common knowledge (integration) and diversified knowledge (decentralization). The difficulty to maximize both of them independently is justified by limited rationality. The problem will then be to find a trade-off between these two knowledge types in order to ensure on the one hand maximal information about the external environment, and on the other, to improve coordination.

It is shown that if coordination among activities is more important then correct aggregated decisions, it will be optimal to respect the informational specificities of the decision units. Furthermore, when there is a high degree of interdependence among activities, the different units will, in order to improve internal coordination, react weakly to environmental changes. Common knowledge seems then to raise the flexibility of responses, whereas differentiation limits this flexibility. The relative importance of diversified knowledge in comparison with common knowledge implies according to this model, two conflicting effects: it enriches the stock of information available

in the firm and reduces flexibility in order to improve coordination among decisional units.

The contribution of Crémer does not explicitly study the evolution and development process of such a common knowledge which in his model is exogeneoly given. If we want to clarify the capacity of firms to generate a common knowledge, allowing them to develop coherent local learning processes, it will be necessary to consider the common knowledge as an endogeneous variable of the system.

Such an approach is used by Marengo (1990, 1992) who formally explores the function of a common knowledge base through a dynamic model (simulation). He compares different organizational structures (differing in their decentralisation and centralisation rates) relative to their capacity to develop and adapt this common knowledge base under different environmental conditions (stable, uncertain, higly disturbed).

The simulations show that a flexible adaptation to a regularly changing environment requires local experimentations and a high degree of differentiation between the different local learning processes. In such an environment the existence of a simple set of rules seems sufficient to guarantee coordination among units. On the other hand, within an unpredictable environment, the performance of the firm improves with the importance of hierarchical messages and decreases with decentralized experimentation.

Unlike Aoki, emphasis is put in this model on the role of hierarchy concerning the development and diffusion of competences and organizational codes which guarantee an efficient coordination of local learning processes.

The transition from this local learning to organizational learning is ensured through hierarchical coordination: "effective decentralisation seems based on bottom-up knowledge and information flows, more than on the horizontal information flows emphasized by Aoki. If the correct emphasis is placed on knowledge and learning, higher degrees of decentralized learning are not necessarily conducive to higher degrees of organizational learning, but only to the extent in which they can be pulled together and made coherent with the overall organizational learning process". What is outlined in Marengo's contribution is the integrative capacity of an hierarchy.

Yet, the efficiency of coordination among different sub-systems is not only due to vertical flows, but depends also on the horizontal structure implemented in the firm. Horizontal integration should be a critical factor in achieving a global coherence of the local learning processes. The two integration approaches proposed by Aoki and Marengo should therefore be considered as complementary.

We think that the main contribution of horizontal integration is in:

– improving the horizontal exchange of tacit knowledge;

– facilitating the vertical information and tacit knowledge flows;

– facilitating the adoption and diffusion in the shop level of new standards and procedures developed by the Planning Office;

– facilitating the adherence to a general unique objective based on centralised planning.

IV. INCENTIVES AND INTEGRATION

The integrated structure and the importance of horizontal coordination within this structure require some complementary or alternative approaches to the standard Principal-Agent theory. These approaches have to insist on "dynamic flexibility". On the other hand, it seems necessary to review the prevailing concept of horizontal cooperation in the standard Principal-Agent theory which merely consists in considering it as a collusion between agents at the Principal's expense.

IV.1. Incentives and learning

If we adopt the point of view of organizational learning, the optimal incentive schemes proposed by the Principal-Agent theory are not completely satisfactory anymore. According to this theory, the divergence of preferences and objectives between agents and the Principal implies inefficient solutions. Asymetry of information and interest conflicts lead mainly to strategic behavior (hidden action, hidden information, free riding). However, as pointed out by Cohen (1987), if we suppose that the agents have a limited rationality and the environment is disturbed, the divergence of preferences can imply other effects than those generated by the strategic use of informational asymetries. Cohen (1984) shows that diversity concerning preferences and objectives in a disturbed environment where learning and creation (innovation) are the main factors of success, is conducive to higher performance. The collective advantage of this aspect of diversity is also pointed out by Schelling (1978) in the Prisonner's Dilemma with N players.

The main point in the standard Principal-Agent theory is the optimal allocation of efforts among tasks. The objective is efficiency. But if we are interested in organizational learning, the objective should be essentially dynamic flexibility. The incentive schemes should therefore allow the

organization to respond, continously and in a satisfactory way, to a perpetually changing and unpredictable environment.

In a static and rational framework, the importance of such dynamic flexibility cannot be fully taken into account, because the question of uncertainty refers mainly to the observability of agent's actions. The concept of flexibility used is the static one and consists in introducing "multi-competence" agents (Holmström and Milgrom, 1991). The aim is to find incentive schemes in order to optimally control the agents and their pre-determined actions. Holmström and Milgrom show that, when some productive activities are too uncertain, an optimal job design would consist in reducing the agent's flexibility between different activities and to specialize "some employees in activities that are hard to monitor and others in activities that are easily monitored". This conclusion however, limits the possibility of a collective learning inside the firm. The purpose is focused on the homogeneization of agents in order to make monitoring easier.

In a disturbed environment, the search for optimal monitoring devices can no more be appropriate. The design of incentive schemes ensuring some "dynamic flexibility" and learning will have to be devised. If for instance the environment is ambiguous, there will be several representations of the world, and the problem will be to design incentive schemes leading the agent to choose the right representation (March and Olsen, 1975).

IV.2. Integration and cooperation

It is no more valid, in an integrated structure, to consider that horizontal cooperation is always harmful to the Principal. In such a setting, cooperation can be an essential component of teamwork and horizontal coordination processes. Such processes require collective work and the execution of a set of integrated activities. The interpersonal competences are crucial to ensure a good coordination of these activities. The design of incentive schemes contributing to the acquisition and development of these inter-agent competences should be one of the main tasks of the Personal Management.

Some recent models refine the notion of cooperation and distinguish several horizontal contracting forms:

- risk sharing (payment pooling);
- effort sharing (effort pooling);
- risk and effort sharing (effort and payment pooling).

Payment pooling only reduces the welfare of the Principal and is considered as a collusion among agents (Tirole, 1986).

Other contributions like those of Ramakrishnan and Thakor (1991), Holmström & Milgrom (1990) and Varian (1990) suppose the perfect horizontal monitoring among the agents as given and show that this will enable them to pool not only their payments but also their efforts. The benefits of such a cooperation are explained by a better risk sharing (Ramakrishnan & Thakor) or a lower risk aversion (agents act like a syndicate) (Holmström & Milgrom) and a better coordination of activities as well *ex ante* (better knowledge of the teams specific attributes) as *ex post* (agents proximity to each other). It is shown that horizontal contracting is welfare improving only if agents possess a private information not available to the Principal. This is the case when agents observe their respective activities and have therefore the possibility to cooperate in their effort levels.

The main purpose of these models is to compare the relative efficiency of two types of coordination – competition and cooperation – and to justify their simultaneous existence inside the firm (team spirit and career development). Relative efficiency is essentially studied through the following parameters:

- absence or presence of mutual monitoring;
- technological independence among activities;
- stochastic correlation among activities;
- separability or complementarity of activities.

Ramakrishnan and Thakor explain the preference for one or the other incentive mode through the definition of the activities of the firm. When uncertainty is low, workers tasks can be precisely planned and the optimal organization would be (particularly when stochastic correlation is high) to implement a competitive incentive scheme. But when uncertainty is high, activities can be no more clearly defined. Stochastic correlation plays in this case a less important role and a cooperative scheme will be prefered.

As outlined by Varian (1990), horizontal coordination can also imply an exchange of information among agents and influence their world representations. Varian shows that under some specific conditions this can improve the surplus of the firm.

Generally, these models view horizontal cooperation as interesting when it allows to substitute hierarchical monitoring by a more efficient way of monitoring agents (mutual monitoring). Cooperation is therefore just another way to coordinate individual interests inside the firm. But the collective nature of the firm is never taken into account. The model developed by

Kandel and Lazaer (1992) is very explicit about this problem. They introduce team pressure as a means of coordination among agents in order to avoid the possibility of free-riding. They show that such a peer pressure, inside a team guided by norms, can sometimes lead to opposite effects: on the one hand, it disciplines the team members and on the other punishes individual members when they exceed the norm practised in the team. Under such a condition the agents' effort level will be the same as when there is no mutual monitoring.

According to these models, the advantage of horizontal coordination of activities consists mainly in diminishing the strategic use of information assymetries. Therefore, the criticism addressed to hierarchical monitoring is also legitimate concerning mutual monitoring; namely in a disturbed environment, monitoring as a means of coordination can no more be appropriate when the main objective is to put forth coherent local learning processes and the evolution of norms in order to adapt to environmental changes.

We think that an approach in terms of trust and reciprocity among agents is more appropriate if we want to study such learning processes. Some models, like those of Drago & Turnbull (1988), Itoh (1991) and Lazaer (1989) study the possibility of cooperation through incentive schemes (individual or collective), without introducing the necessity of mutual monitoring. Other contributions (Fung, 1991), stress the importance of trust in coordinating activities. But the research concerning these alternative incentive forms is still in an infantile phase.

According to us, it will be important to spent more time to study the development and constitution dynamics of such network relations based on trust and reciprocity, if we want to know how to generate coherent local learning processes. It is clear that such dynamics are mostly influenced by cultural and institutional factors regulating the relations among firms.

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