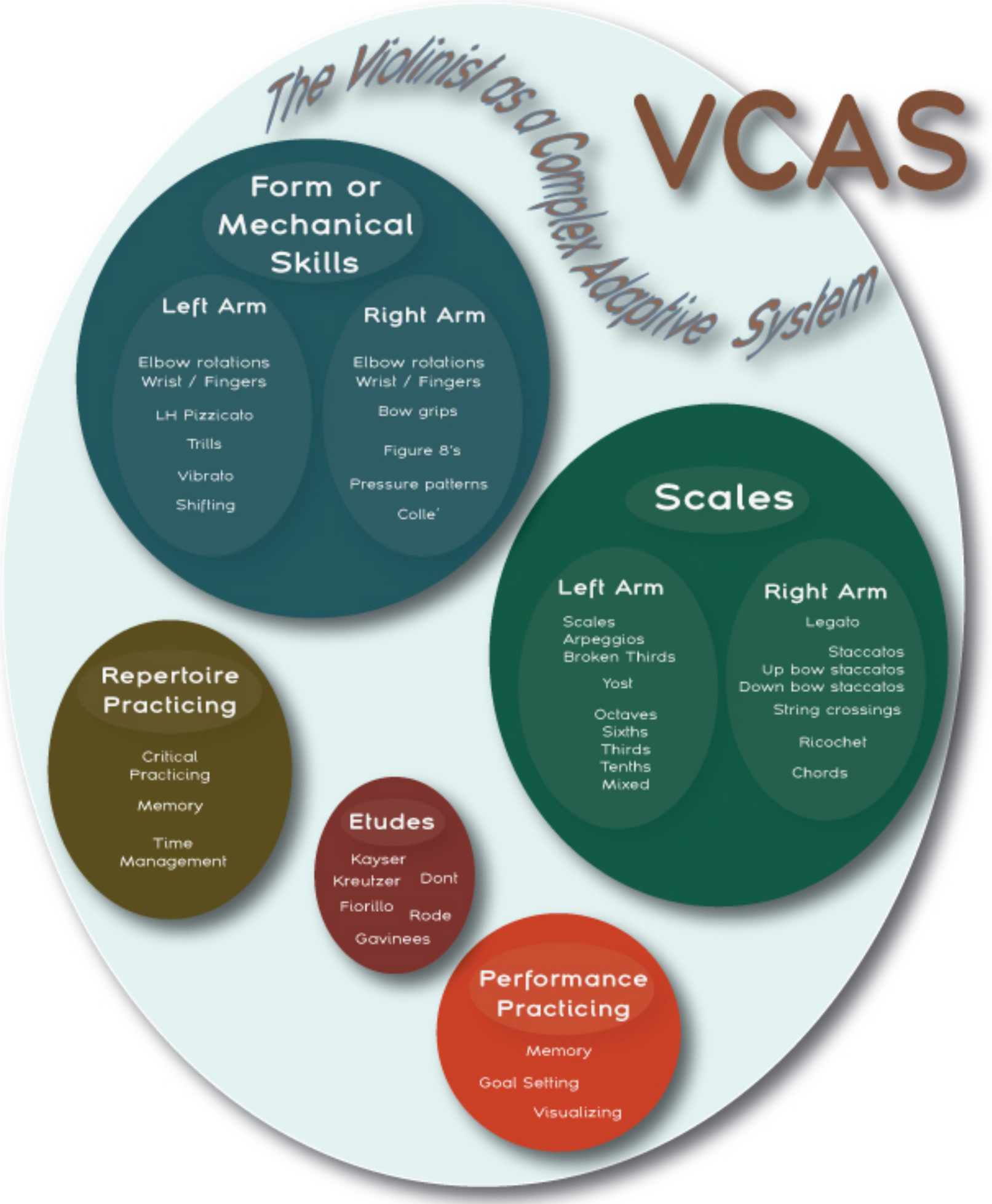
The Violinist as a Complex Adaptive System
VCAS
Form or Mechanical Skills
Left Arm
Elbow rotations
Wrist / Fingers
LH Pizzicato
Trills
Vibrato
Shifting
Right Arm
Elbow rotations
Wrist / Fingers
Bow grips
Figure 8's
Pressure patterns
Colle'
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Scales
Arpeggios
Broken Thirds
Yost
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Sixths
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Tenths
Mixed
Right Arm
Legato
Staccatos
Up bow staccatos
Down bow staccatos
String crossings
Ricochet
Chords
Repertoire Practicing
Critical Practicing
Memory
Time Management
Etudes
Kayser
Kreutzer
Dont
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Rode
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Performance Practicing
Memory
Goal Setting
Visualizing

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DIVERSITY, KNOWLEDGE AND COMPLEXITY THEORY: SOME INTRODUCTORY ISSUES

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This paper will discuss some introductory issues related to the role and importance of microdiversity of agents in the context of business networks. Traditional views emphasise the importance of connectivity in the making of industrial clusters, but neglect the crucial role of microdiversity. Microdiversity is important to achieve adaptive behaviour in the presence of environmental uncertainty. Diversity acts as a reservoir of potential strategies against unpredictable environments. Secondly, the formation of business networks is explained in terms of mechanisms generating diversity. Networks emerge as the organisational form in which the diversity of agents can self-organise. This paper suggests that the issue of diversity can be used to discriminate between the model of organisation based on rational allocation of resources — the firm — and the model of organisation based on emergence and self-organisation — the network. The paper concludes that the former is a diversity-reducing mechanism, whereas the latter is a diversity-enhancing mechanism

Keywords: complexity, knowledge, networks, microdiversity, clusters

Introduction

The study of complex systems is based on the assumption that there is more to a system than the sum of the components and the linkages that compose the system — be the system a city, a colony of ants, a brain's neurons or a cluster of firms. Systems show properties that are truly emergent, irreducible

to explanations that take into account only lower level components' properties. Simple experiments (Kauffman, 1995; Nicolis & Prigogine, 1989) demonstrate that the transition from an aggregate to a system (Juarrero, 1999) takes place when a phase transition alters the fundamental dynamical properties of the system's components. This corresponds to a transition from a regime of independence, where the components' properties are largely independent from their context, to a state of co-evolution. In the new state the co-dependence among components generates a *systemic context*, that affects the properties of the components. As Rescher (1979: 109) claims: "*The root idea of system is of integration into orderly whole that functions as an organic unity.*" The overall set of models, frameworks and theories inspired by the principles mentioned above are known under the umbrella term of complexity theory.

A distinctive aspect of complexity theory concerns the dialectics between the properties of agents and the properties of systems. A system emerges when the self-organisation of agents generates ordered structures at the system level. Two properties are at the base of self-organisation: connectivity and microdiversity. Whilst the former is the object of a large literature, the latter is relatively unexplored. This paper will focus on the role of microdiversity in the context of socio-economic networks.

This paper is structured in the following way. In the first section, I discuss the importance of diversity and show the centrality of diversity in networks and complex systems. Secondly, I explain the formation of business networks in terms of mechanisms generating diversity. Thirdly, I describe some elements of the complexity theory and show how complexity is a useful framework to describe the formation of networks. Fourthly, all the previous concepts are merged around the idea of distributed systems of knowledge. Finally, there are some concluding remarks.

The Importance of Diversity

The role of socio-economic diversity has received marginal attention in economics (Grabher & Stark, 1997; Metcalfe, 1994; Saviotti, 1996; Saviotti & Mani, 1995; Stirling, 1998). Diversity is seen as necessary to promote an innovative environment, to avoid technological lock-in, to promote political representation and to balance different political views (Stirling, 1998). In complexity theory (Holland, 1995; Kauffman, 1995), internal diversity is seen as a fundamental requisite of systems in order to achieve a higher rate of adaptability. Diversity is also a prerequisite for self-organisation. I shall in the following examine these aspects of diversity.

Ashby's (1960) principle of requisite variety states that the internal variety of a system should match the variety of the external environment. The response

capability of a system should be at least as varied as the set of stimuli that the system receives from the environment. In this way, the system can successfully respond to environmental threats and opportunities. For example, a simple environment generates a simple set of stimuli, which in turn can be faced in relatively simple ways by organisations. This is one dimension of diversity, a static dimension. In stable environments, once the right degree and kind of diversity are achieved, there is no further need to modify the system's diversity. The situation changes if the rate of environmental change becomes faster. In this case, matching a fast changing environment demands adaptability, that is, the capability to change internal functional structure at the desired rate. What becomes critical then is the speed of change. Interestingly, in evolutionary biology, adaptability is connected with internal diversity. For instance, Fisher's famous evolutionary theorem makes evolutionary rate of change (adaptability) dependent upon genetic variance. On a similar note, Gould claims that genetic variance based on redundancy (including the bits of DNA that seem useless) constitutes a pool of possible responses to be activated when established co-evolutionary strategies fail.

> "*Evolution is a messy process brimming with redundancy. An organ might be moulded by natural selection for advantages in one role, but anything complex has a range of other potential uses by virtue of inherited structure … any vital function restricted to one organ gives a lineage little prospect for long term evolutionary persistence; redundancy itself should possess an enormous advantage*" (Gould, 1993).

Therefore, a system that exhibits both diversity and redundancy (redundancy ensures that internal diversity does not result in isolated fragments) is more capable of adaptive behaviour than a more simple system. Internal diversity then plays a double role: on the one hand it provides a static matching with the environment, and, more importantly, on the other hand, it provides the key element for matching environmental changes over time. Interestingly, when environmental change becomes turbulent and characterised by uncertainty, even the capability of fast tracking environmental changes may not be enough for survival. Radical changes may demand either a structural reconfiguration of the organisation or the emergence of new types of organisation. Under these circumstances, a strategy based on matching predicted environmental change turns out to be impossible to devise and implement. In this issue, Allen (2001) introduces the *law of excess diversity*, that is, the idea that a sustainable and successful evolutionary strategy requires an amount of internal diversity superior to that of the environment. Allen suggests that agents need to have a stock of potential strategies to be set off in the face of unpredictability in environmental change. To conclude, diversity constitutes an important element in short- and long-term adaptability.

Self-organisation can be described as the establishment of coherence in the aggregated behaviour of agents. However, in order to give rise to stable structures of order, self-organisation requires the presence of some sort of organising principles, able to generate an organic unity and a new level of organisation. One of such principles is the autocatalytic set (ACS) (Eigen & Schuster, 1979; Juarrero, 1999; Kauffman, 1993). Autocatalysis takes places in a hypothetical aggregate of agents when a set of catalytic reactions close onto itself. For this to happen, three conditions have to be present: (1) a sufficient amount of agents' diversity; (2) a mechanism that ensures interaction and feedback; and (3) a particular architecture of the interactions able to channel and limit the potential explosion in diversity (Ingber, 2000; Kauffman, 1993). Let us focus only on the first condition. The chance that a particular molecule (or agent's property) catalyses a reaction (a social or economic interaction is catalysed when some form of increasing returns mechanism is triggered by the catalyst) is in general relatively low. Therefore, in order for a sufficient number of catalytic reactions to be present and achieve closure, a critical amount of internal diversity is necessary. The closure of the set will have two effects: (1) it will generate selective amplification at the micro level and (2) it will cause the emergence of order creation at the macro level. Selective amplification is a consequence of the auto-referential aspect of the ACS. In fact, the ACS will amplify the concentration (or number) of the agents that are part of the set and will filter out those that are not. As a result of this, the set will transform the previously existing aggregate of agents into a system based on the autocatalytic dynamics, which works as an autopoietic (Maturana & Varela, 1992) organising principle. The dynamic order generated by the double effect of the autocatalysis, that is, selection and organisation of agents, creates at once boundary, structure, and hierarchy within the system. The set can self-perpetuate and, under certain conditions, lead to self-replication. The dynamics of the ACS constitutes the identity of the system, insofar it defines the rules of development of the system and the boundary of the system. The ACS is an example of an order creation mechanisms that depends critically for its start on internal diversity. It is a way in which internal diversity self-organises and causes the emergence of a system.

To summarise: (1) adaptive strategies are more successful if agents and systems are internally diverse; (2) the transition from an aggregate to a system is also dependent upon internal diversity. However, apart from adaptability and self-organisation, there is another important aspect of diversity which concerns the way in which the organisation of diversity takes place. I suggest that networks of autonomous units constitute the organisational form that allows diversity to self-organise. The next section will be devoted to these networks.

The Diffusion of Geographic and Virtual Networks

It is suggested by many authors (Arthur & Rousseau, 1996; Gulati *et al*., 2000; Kogut, 2000; Nohria and Eccles, 1992; Powell *et al*., 2000) that the fundamental unit of analysis of organisational studies is shifting from the isolated firm to the network of organisations. This transition reflects the widely acknowledged phenomenon of disintegration of traditionally integrated structures of business into more complex networks of independent parts (Eisenhardt & Galunic, 2000; Evans & Wurster, 1999; Grabher & Stark, 1997; Malone & Laubacher, 1998; Nishiguchi & Beaudet, 1998; Pettigrew & Fenton, 2000; Porter, 1998; Powell, 1990; Storper, 1997).

Geographic clusters represent a well-known example in economic geography (Storper, 1997). Geographic networks of small firms emerge when the process of vertical disintegration (triggered often by a supply or demand shock) is met by a parallel process of agglomeration over a limited territory. This counterbalances the increase in transaction costs and allows the coordination of a supply network (Piore & Sabel, 1984). However, the disintegration of the traditionally integrated structures of business is being accelerated by the digital environment. In this context, virtual networks are emerging, facilitated by new systems of coordination (more space and time independent) provided by information and communication technologies (ICTs) (Romano & Passiante, 1997). These technologies have made possible the formation of purely virtual business models, such as e-bay (Passiante & Andriani, 2000) and Linux (Raymond, 1999), that offer a paradigmatic example of the power of networks, provided by ICTs in cyberspace. In these virtual networks, fluid — sometimes structured, sometimes self-organising — systems of suppliers, distributors, commerce service providers, infrastructure providers and customers use the Internet to create value for customers and wealth for their stakeholders.

The main characteristic of virtual clusters is that each firm focuses on a limited set of core activities and outsources virtually every other function; each participant in the network adds one or more distinct aspects of product/service value for the end customer, by exchanging information with other members (Ticoll *et al*., 1998). Recent studies on virtual networks show how the ubiquity, the bandwidth, the reliability and the new functions of the ICTs are the enabling factors of these networking processes (Davis & Botkin, 1994; Rayport & Sviokla, 1995). Each single participant of a virtual network becomes an internetworked enterprise (IE) (Tapscott *et al*., 2000), that:

— has the power and capacity to open channels of communications and collaboration within an office, across space, and across time: collaborative work increasingly takes place among independent team-based structures, on high capacity networks (Tapscott, 1996);

— has a flat organisation, which is replacing traditional vertical hierarchies (Zenger & Hestley 1997): teams behave as suppliers and customers towards other teams that are both internal and external to the organisation (Bartlett & Goshal, 1995); this organisation allows the IE to become highly proactive, responding more quickly to changes in the competitive environment and customer demands (Valdani & Ancarani, 2000);
— may be modelled as a node of a virtual network, where boundaries between different nodes are blurring. While a traditional firm defines its assets only in terms of the resources it owns, an IE also includes (as assets) the relational ties of its network.

But, why do these learning networks — virtual and geographic — emerge? They do so mainly as the response of firms and organisations to a series of factors: increased environmental uncertainty, explosion of connectivity, gradual disappearance of information asymmetry, and increased pace of technological innovation.

Uncertainty

It is widely accepted that one of the effects of the communication technology revolution of the 1990s, coupled with the forces of globalisation and liberalisation, has been the increase in environmental risk and uncertainty that organisations have to face. The reaction to it has widely been the disintegration into networks. The increase in complexity of value chains has forced organisations to limit exposure to risk and uncertainty by adopting a simultaneous strategy consisting of, on the one hand, specialising in core competencies and, on the other hand, increasing the number of links with suppliers, customers, partners, etc. The net result of these processes is the formation of network within and across organisations. Indeed, unlike the traditional industrial corporations, networks are flexible organisations, “open systems” which adapt continuously to their changing environment by starting new strategic alliances, by changing interactions among network actors or by offering new products and services to network clients. This is the result of a dense web of interactions among partners: production and transaction processes are based on intermodality and complementarity instead of substitution, on the assumption that the best way to handle risk is to share it by leveraging capabilities and resources of many players. Networks are then the global effect not of a deliberate strategy of a leader, but simply of the level of coherence that takes place among single actors that compete in a highly risky environment. An outstanding example is given by the networking process that is happening in the financial industry. To face the high risks of this competitive

space, the old integrated business model — with financial products/services realised and delivered through proprietary distribution channels — is evolving towards new assets, made up of a lot of autonomous small and medium enterprises (SMEs) that compete for different financial products/services. Banks are becoming the facilitators of the SMEs' negotiation activities (Evans & Wurster, 1999).

Information asymmetry

Organisations are structures devoted to coordinating the flow of information across internal boundaries (between groups, departments, divisions) and external boundaries (suppliers, partners, customers, stakeholders). Management can be described as the set of activities aiming at governing the processes associated with the information flow and knowledge coordination and specialisation. As Evans and Wurster (1997) claim: "*information is the glue that holds together the structure of all businesses*". The structure, hierarchy and boundary of an organisation have the function of protecting and maintaining the information asymmetry that constitutes the *raison d'être* of the organisation. If the informational glue that keeps organisations together disappears, then the result will be the blowing apart (unbundling) of the organisation into its constituent functions. Interestingly, all else being equal, the first elements to dissolve will be the centralised coordination of the different functions that make up the organisation. This will leave a network composed of the functional parts of the disaggregated organisations. But this is not all. The deconstruction of organisations generates new business niches at the interfaces between the newly interdependent companies. These opportunities are quickly occupied by new organisations, thereby reinforcing the tendency to network structuration.

Rate of innovation

Together with the transformation brought by uncertainty and informational changes, the increased rate of technological innovation appears to be causing tectonic shift in the structure of industries. Traditional boundaries between sectors are being redefined (witness, for example, the convergence between the television, telecoms, information technologies and entertainment industries). On the one hand, convergence reinforces the effects of uncertainty. On the other hand, it generates the explosive diversification of the players: (1) around the newly created interfaces between sectors once independent; (2) around the new radical innovations that have generated convergence in the first place. The effect of these two forces is an enlarged technological and business opportunities landscape that organisations can pursue.

Change is sometimes so rapid that the analogy with chaotic ecologies holds. The *red queen* tells Alice that in the *Wonderland* : "*It takes all the running you can do, to keep in the same place*". Thus, the red queen paradox (Kauffman, 1995) indicates that, in a network that has to bear the consequences of an explosive increase in its internal or environmental diversity, the rate of change may become so rapid as to inhibit the forces of selection to operate. Under these circumstances, the speed at which the economic system continuously produces new innovations prevents the emergence of a dominant design (Anderson & Tushman, 1997; Gould, 1997). The system persists in the fluid phase of innovation and no freezing around a dominant design takes place (Abernathy & Utterback, 1978). If the effect of the learning curve (Abernathy & Wayne, 1974) is absent and if economies of scale are prevented from operating, then the transformation of the network structure into the more traditional integrated organisation will not take place (Saxenian, 1994).

The three causes mentioned above; increased uncertainty, disappearance of information asymmetry and faster rate of innovation (save the case in which innovation leads to the emergence of a dominant design) are diversity-increasing mechanisms. Stated another way, the same mechanisms that enhance networks formation and expansion also act to increase diversity. This is an important point for it suggests that the network emerges as the natural organisational form for a diversified system. The relationship between network as an organisational form and highly diversified systems can be extended, taking into consideration the fact that diversity could be considered as the main differentiating factor between firm and network.

Diversity tends to create more diversity through innovation (Grabher & Stark 1997; Kauffman 1995; Metcalfe & Gibbons, 1988; Stirling, 1998). In other words, diversity itself, above a threshold, seems to become autocatalytic. However, an increase in internal diversity is likely to cause both a reconfiguration of links and the appearance of new types of agents. In so doing, it is likely to introduce centrifugal forces that could potentially disrupt the system.

Bureaucratic organisations in general find it difficult to cope with an unplanned increase in internal diversity. This is because the mechanism of rational allocation of scarce resources requires knowledge of types and probability distribution of outcomes for the planning exercise to take place. Increase in internal diversity will create resources from the bottom that are largely unaccounted for, and regarding which, no description is present. A bureaucratic organisation could therefore be easily disrupted by changes in its internal diversity and will in general tend to keep the diversity creation mechanisms under strict control. This type of organisation can be described as a hierarchically structured closed system that behaves as a monolithic network (Antonelli, 1995). The exploration and exploitation

(March, 1989) of market and technological opportunities will generally take place within a single technological trajectory (Dosi & Orsenigo, 1985) and dominant production paradigm. Therefore, "o*rganisation by firm is variety reducing*" (Kogut, 2000).

Distributed networks obey a different logic. They are based on high amount of redundancy and modularity. The allocation of resources is emergent, that is, it is based on self-organisation. In clusters, either virtual, such as Linux, or geographic, such as the districts in Italy (Piore & Sabel, 1984), evolutionary changes are based on massive parallelism of resources and competencies. Any increase in the degree (or kind) of internal diversity is met by a rapid reconfiguration of links [as suggested by Arthur *et al*., (2001) and Maskell (2001) in this issue]. The modularity helps the system to pursue diversity increasing changes at the agents' level and — due to the self-organisation of links — also at the network's level. Essentially, a distributed self-organising network is the locus where a high diversity of agents (organisation) coexists with the organisation of diversity (Grabher & Stark, 1997). I suggest therefore that a distributed network based on self-organisation principles is a diversity-increasing type of organising production and innovation.

Complexity as a Dynamic Theory of Emergent Order in Networks

The transformation of organisations into networks causes a coordination problem under at least two points of view: first, the number of units to coordinate rises; second, the autonomy and diversity of those units increases as well. Adding technological turbulence to the picture makes the task of managing networks a central challenge for today's management. On the other hand, complex systems reveal an interesting property: they seem to require less central management as they can self-manage. The Internet is a fascinating example: nobody manages the Internet and nobody "project managed" the Internet as a new product development experiment. One could even suspect that had the Internet been "managed", it would never have seen the light of day (Malone & Laubacher, 1998). The community of Linux (Raymond, 1999) managed to develop what is hailed as the most stable and reliable computer operating system without being managed (in the usual sense of the term) at all. This property of large systems to self-manage has something to do with the "invisible hand" of Adam Smith, and is not far from the Darwinian argument of evolution by means of massive parallelism in experimentation (Axelrod & Cohen, 1999). As this is a crucial point, I will spend a little time on it. Self-management is a way to describe the tendency that complex systems show to self-organise around a pattern of relationships.

There are really two aspects of self-organisation: first, the aspect of "generative rules", widely described by the Santa Fe school of complexity (Holland, 1995; Kauffman, 1995; Resnick, 1997; Waldrop 1992). This approach, very much bottom-up, shows that complex adaptive systems and behaviours at the system's level can emerge from the interactions of agents, whose behaviour is driven by a limited set of simple rules. The example of a colony of ants (Hofstadter, 1980) is famous. This approach introduces a duality between the agent's level and the system's level, characterised by a strongly anti-reductionist flavour. Complete knowledge of the agents' behaviour will not allow the prediction of the system's behaviour. On the whole, however, the "generative rules" approach overlooks the interaction of the system with the environment. The properties of the systems seem to be completely bottom-up and emergent, and therefore resistant to external control and management. In addition, although the system shows the typical dynamics of emergence of collective properties, the "generative rules" approach has some problems in introducing reflexivity of the agents (the capability to figure out the macro-context (Storper, 1997)) and *double-loop learning* (Argyris & Schon, 1978), as a result of experiential learning. Also, this approach assumes the homogeneity of agents. As a result, although such systems show interesting dynamical patterns based on self-organising behaviour, the range of order creation mechanisms they exhibit is fairly limited (Allen, 2001).

A complementary line of thought (Allen, 1997; Nicolis & Prigogine, 1989; Prigogine & Stengers, 1997) stresses the importance of the interaction with the system's environment. Such systems are seen as open (*dissipative*); the flux of energy/information across the boundary becomes the driver of the internal state of organisation. The famous Bénard experiment indicates that self-organisation depends on the constraints imposed by environmental external parameters. Self-organisation becomes, then, a consequence of a "negentropic" process, whereby the energy, matter and information imported from the environment drive the selective amplification of catalytic processes within the system (McKelvey, 2001; Nicolis & Prigogine, 1989). The dissipation of energy outside the boundary of the system allows the emergence of order within the system. But, self-organisation emerges only in a precise window of environmental constraints. Outside of that window, the system goes either into a static equilibrium that implicates the inability to change and in the long term death or into a chaotic state. In both cases, the order that characterised the state in between, by which a coherent set of correlations between agents allowed the emergence of collective structure, disappears.

Distributed Knowledge

I would like in this section to extend some of the points developed in the previous parts to the issue of distributed knowledge systems. We have seen that the network type of organisation is diversity increasing whereas the firm type of organisation is diversity reducing. The two types of structures also differ in terms of the knowledge structures they generate and the way those structures are managed. These issues are related to two intriguing questions regarding the locus of learning. First, does learning take place only at the level of agents or also at the level of systems? Second, is the system's knowledge an emergent property of the self-organisation of the different specialisms of the individuals composing the system?

A large part of the traditional knowledge management literature points out that only individuals can learn (Grant, 1996; Nonaka & Takeuchi, 1995) and that knowledge is stored in individuals' heads. This position comes as no surprise when one considers that knowledge management has mainly been applied to the context of firms and used as a management tool or framework to support the decision-making process. Knowledge is the ultimate competence (Prahalad & Hamel, 1990; Spender, 1994) and the real terrain of competition (Davenport & Prusak, 2000). This position represents a crucial aspect of the resource-based view of the firm (Grant, 1991), whereby companies are endowed by their histories with unique resources (Hall, 1992). To stay ahead of the game, firms need to continually regenerate their dynamic capabilities and to use the newly generated dynamic capabilities to sustain and protect existing markets and leverage, and create new competitive niches. Knowledge management provides a powerful framework and a set of tools to achieve that purpose. This comes in two steps: (1) it is necessary to manage the knowledge processes (creation, codification and diffusion) at the individual level; (2) there is a need to coordinate and integrate the knowledge processes (achieved by means of conversion of one type of knowledge into the other (Nonaka & Takeuchi, 1995) in order to generate organisation-wide dynamic capabilities (Grant, 1996). Capabilities are built by carefully integrating individual specialised knowledge into a predesigned plan (Prahalad & Hamel, 1990). Because the mechanisms of coordination and integration of knowledge are designed and implemented according to an explicit strategy, an organisation develops a strong identity, based on the coordination and integration mechanisms. This identity limits microdiversity and therefore forces the organisation along the path of incremental innovations. The stress on individual learning and "management" of knowledge ultimately reflects the view of management as planning and design in centralised structures.

A different stream of the knowledge management literature (Brown & Duguid, 1991; Cook & Brown, 1999; Tsoukas, 1996; Weick & Roberts, 1993) takes

a different view that alongside individuals, systems (firms, organisations) can also learn. According to the latter view organisational knowledge cannot be reduced to the sum (however coordinated) of individuals' knowledge, but is a fundamental property of systems. For instance, one of the major insights of evolutionary economics (Nelson & Winter, 1982) is that organisational routines represent the analogy of individual skills. Organisational routines are collective and complex patterns of quasi-automatic reactions driven by a set of preselected stimuli, operating on the basis of collective experiential learning, largely unconscious to the individuals involved. As skills, routines are acquired via collective learning by doing. The retention of routines is based on collective remembering by doing. In both cases, the *doing* does not require full consciousness, either at the individual (Squire & Kandel, 1999) or at the collective level.

The execution of a routine requires the spontaneous coordination and sequencing of a set of responses with a set of stimuli (which may come in any order). The communication system is based on a tacit language, full of locally understood words. Finally, the environment, in which the execution of the routine is carried out, is not separated by the routine itself, but constitutes the context in which the interpretation of the stimuli takes place. It is this contextual element of the organisational routine that creates the impossibility of reducing the routine to the sum of its individual agents' actions. Again, as for skills, the memory of the routines is stored in a distributed social network. The contextual dimension of organisational routines [as with similar organisational processes, such as communities of practice (Brown & Duguid, 1991; Wenger & Snyder, 2000)] makes them very difficult to manage, due to the inherent idiosyncrasy and diversity with which the elements of the routine become manifest. The unpredictability associated with diversity is disruptive to top-down management schemes. This is why, as suggested before, diversity requires a form of organisation that can thrive on variety, that is, the network.

The processes of knowledge creation and diffusion in a highly distributed system, such as a cluster of small- and medium-size firms (typical examples are Silicon Valley or the textile cluster in Prato, Italy), are largely spontaneous, scarcely codified and very fragmented. Individual companies and free-lance agents (Malone & Laubacher, 1998) hold only a fraction of the knowledge necessary for the delivery of a service or the manufacturing of a product. The disintegration of competencies (Maskell, 2001) makes the agents dependent on one another. At the same time, it raises the issue of integration of the fragmented competencies in a coordinated web of interactions, in relationship of competition and collaboration with each other.

The high social connectivity within the local system forces the rapid embeddedness of minute improvement — the execution of a skill (Becattini, 1998), the optimisation of a measuring device, or the intuition regarding set of colours or shape for the next fashion season — in a set of intra- and inter-organisational routines. Innovations, big or small, become part of the local system of knowledge via the rapid integration in the existing set of routines, belonging to no one but to the network.

The integration of activities, processes and competencies transcends any single organisation in the cluster and is not coordinated by any centralised authority. This multiple-level system of knowledge emerges in the co-evolutionary dance between the adaptive tension (McKelvey, 2001) set by the multiple set of constraints determined by the relationships among organisations (Juarrero, 1999) and the external set of environmental constraints set by the industry and market forces. The tacit integration of the different packets of knowledge and information builds a coherent system of knowledge and enables the cluster to achieve world class performance, business resilience, adaptability and world class rate of innovation.

The three distinctive features of networks, namely, fragmentation, integration of innovations and emergent coordination require the formulation of new interpretative concepts to explain the spontaneous emergence of order [Kauffman's "*order for free*", (1995)], that is, the property of systems (in our case industrial clusters) to self-organise around bottom-up emerging structures.

In contrast to command and control or bureaucratic systems, emergent coordination does not rely on organising principles that rest outside the system itself. Instead, it is based on the network of interactions exchanged by the agents in a cooperative and competitive way. The structure of the coordination is then the network itself. Most of the social transactions within the network are nothing else but a form of knowledge exchange. As Kogut (2000) states: "***the network is knowledge***, *not in the sense of providing access to distributed information and capabilities, but in representing a form of coordination guided by enduring principles of organisation.*"

Concluding Remarks

What I have tried to illustrate in this paper can be synthesised in a few lines. Microdiversity plays a crucial role in the dynamics of complex systems. Microdiversity is necessary to achieve a balanced response to the external environment, to enhance adaptive behaviour and speed up evolutionary behaviour. In the presence of fast-changing environmental conditions, when uncertainty dominates the scene and/or complex systems and environment are co-evolutionary and chaotically linked, a strategy based on complexity matching might not be

enough. The law of excess diversity (Allen, 2001) applies under these conditions. In order to counterbalance environmental uncertainty, agents or systems need a degree of internal diversity higher than that of the environment. The excess diversity acts as a reservoir of potential strategies against unpredictable environments. Microdiversity is also a necessary conditions for spontaneous order creation. Stable structures of order are generated when relationships of complementarity and redundancy are explored and established among diverse actors. The process of order creation is therefore probabilistically dependent upon internal diversity.

The types of structures created by self-organisation of diverse agents show the characteristic properties of networks. Networks emerge then as the organisational form in which the diversity of agents can organise and thrive. This paper suggests that the issue of diversity can be used to discriminate between the model of organisation based on rational allocation of resource — the firm — and the model of organisation based on emergence and self-organisation — the network. The paper concludes that the former is a diversity-reducing mechanism, whereas the latter is a diversity-enhancing mechanism.

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