THE EMERGENCE OF AI AND INNOVATION NETWORKS: CHANGING PERSPECTIVE TO INNOVATION DYNAMICS

Nilanka Chatterjee

Professor, Universal Business School, Karjat, Maharashtra.

Sachin Dubey

Universal Business School, Karjat, Maharashtra.

Abstract

While AI is a burning example of breakthrough innovation that the humanity has witnessed, increasingly AI has impacted various innovation dynamics. The fear element which is associated with AI is also to be pondered upon as it is slowly changing the perspectives of people in terms of employment generation. Within recent research on innovation dynamics modern innovations are viewed neither as the outcome of invention and marketing strategies in individual companies in response to complete knowledge about relevant demand states, nor as fitting the picture of a passive transformation of scientific knowledge into applied knowledge and then - mediated by company R&D departments - into products that are ready for the market. In contrast to the traditional perspective, evolutionary economics and technology studies have created a far more differentiated picture of technology development in which the concepts of uncertainty, lack of transparency, and acceptance play a central role. A central role of this new understanding of structure and dynamics of innovation processes plays the modern concept of self-organisation. Originally developed in the natural sciences it shows how individual actors with divergent interests may co-operate because co-operation reduces the uncertainty of innovation dynamics which is caused by the increasing complexity of modern innovations. Due to this increased complexity "*go-it-alone*" strategies are becoming extremely risky and "*innovation networks*" emerge. The concept of self-organisation shows what the driving force of these networks is, what the social mechanisms of co-ordination are and how the distinction between the network and its environment is made and reproduced.

Keywords: *Innovation, Evolutionary Economics, Techno-Genesis, Innovation Network, Self-Organisation*

1. INTRODUCTION

Innovation theories have regained their popularity. Reverting back to Schumpeter, who made economists aware of the role of innovations for economic change, the dynamics and structure of innovation processes have become a focus of interest again, not least because innovation has gained new importance as a key term in sociological modernisation theories. The starting point for recent innovation theory is a definition that also goes back to Schumpeter: "*Almost all innovations reflect existing knowledge, combined in new ways.*" (Lundvall 1992: 8) For some time now, the planning, development, construction, production, and marketing of new products and procedures has been perceived as a problem. This problem has two decisive dimensions.

Empirical findings indicate that the *innovation pressure* is expanding continuously because:

- Products are developed increasingly for potential customers and their application context. One can see a transition from the production of unspecific mass goods to the production of special products designed for specific tasks.
- The broader and more rapid deployment of knowledge through new information technologies and the growing importance of knowledge for the dynamics of innovation increase the competitive pressure and, thus, also that of innovation. New products have to be launched on the market more and more quickly if they are to be an economic success.

Parallel to this, *innovation decisions* become increasingly more risky because:

- Innovations are growing in complexity.
- The market is becoming increasingly less transparent and more turbulent, and launching a new product is becoming more of a risk. For a new product, quality alone is no longer decisive for its commercial success.
- The third reason for the increasing risk of innovation can be seen in a growing dependence of the success of an innovation on the available knowledge. Labels such as the "*knowledge society*" and "*knowledge-based industry*" point to a fundamental change in the role of knowledge.

From the current theoretical perspective, innovation is neither an adaptation to perceived needs nor an unique act of (linear) transformation of inventions into products.[1] In particular, the (more meso- and macro-structurally oriented) *evolutionary economics*, but also the (more micro-structurally oriented) sociological oriented *technology studies* rejected the causality assumptions of classic innovation theories in their theoretical and empirical studies and are developing models describing innovation processes as being multi-referential, non-linear, dependent on various framing conditions, and rarely predictable. In contrast to the traditional perspective, modern innovation research has created a far more differentiated picture of technology development in which different concepts of innovation networks play a central role. (Chapter 2) Nonetheless, the theoretical explanation of network genesis, the ways of functioning and negotiating within networks and the mechanisms of *reciprocity*, *preferential treatment* and *learning* remains controversial. With a new model of innovation networks based on the theory of self-organisation these controversies a breakthrough should be possible. In the following we try to develop such a new model in two steps: First we discuss the basic concepts of self-organisation (Chapter 3) and in a second step (Chapter 4) we apply these concepts to the case of innovation networks.

2. EVOLUTIONARY ECONOMICS AND THE SOCIOLOGICAL ANALYSIS OF TECHNOLOGY

Since the beginning of the 1980s, a new direction of research has developed within the conflict between the classic theory of innovation and Schumpeter's approach: *evolutionary economics*. The (neo-) Schumpeterian outlook on innovation through *evolutionary economics* proceeds from a radical criticism of the (neo-) classical theory of technological change. This criticism refers to the theoretical modelling of innovation dynamics (Dosi 1983), to both the theoretical and methodological instruments as well as conclusions of empirical studies (Rosenberg, Mowery 1982), and to the actor-related implicit assumptions on rationality. (See Nelson 1995; Silverberg 1988)

The term *evolutionary* covers the dynamic perspective on economic processes ("*dynamics first*") and the central assumption that the evolutionary explanation of innovation processes must integrate not only the randomly determined variation of elements in the innovation process but also their selection. (See Dosi, Nelson 1994: 154f.) "*Evolution*" implies the interaction of principles of variation and selection and presupposes the heterogeneity of the elements on which both principles impact. (See Marengo, Willinger 1997: 332)

Nonetheless, *evolutionary economics* is not a coherent theory with a common methodology. It is more of a juxtaposition of various approaches sharing the criticism of the neo-classical approach, the rejection of the assumption of rational decision-making, and support for the examination of dynamic processes within the economy. (See Dosi, Nelson 1994) What they all emphasise is, first, that technological change is underdetermined by technological factors, and, second, that successful innovations do not always have to be the best ones, but represent the outcome of multiple and contingent effective factors. In this theory program, technological change is not determined exclusively by either the economy or technology. The openness to design of new technologies on the one side is faced with closure processes and lock-in effects on the other. Both organisational and institutional aspects as well as learning processes on different levels of organisation and society play an important role in formulating the theory of *evolutionary economics.* (See McKelvey 1998)

The theoretical foundations of *evolutionary economics* also draw on different sources: The long tradition of formulating theories in economics on the basis of mechanics has been shifted more strongly toward biological models. Irreversibility in time and the consideration of dynamic processes come to the fore. (See Dosi, Metcalfe 1991) The assumption of complete rationality in actors is replaced by theoretical formulations based on game theory and institutionalism. In recent times, computer simulations have also been used that are based on biological evolutionary theory and work with *evolutionary* or *genetic algorithms.* (See Birchenhall, Kastrinos, Metcalfe 1997; Brenner 1998; David, Kopel 1998)

In a (mostly) broad analogy to evolutionary theory, the following analytical and methodological extensions can currently be recognised in the research program of *evolutionary economics*:

- Analogue to biological evolutionary theory, recent *evolutionary economics* uses the concept of "*fitness*" (Dosi, Nelson 1994) to emphasise the social construction of technology rather than a technological determinism, and thus point to the potential for variation. Accordingly, technological solutions have to only *fit* or *be suitable for* an application context, and not achieve an optimum.
- The selection criteria developed originally for *evolutionary economics* ("*profit*" in Nelson, winter 1982; "*prices*" in Silverberg 1988) are currently giving way to a more complexly constructed selection dynamic. This posits that companies select according to a variety of criteria (capital markets, anticipated profits, market development, economic growth conditions, product strength, prices, distribution conditions, etc.). This multidimensionality of selection criteria challenges *evolutionary economics* to specify the interaction mechanisms through which selection is performed. A further challenge is associated with the above-mentioned extension of the approach through organisational sociology: Selection can no longer be located within an unstructured business environment. In the real world, users are not exclusively selectors but also involved in the shaping of innovations. (See Anderson,

Tushman 1990; Tushman, Rosenkopf 1992; for an overview, Kämper 1995) This follows, first of all, the realisation that innovating companies do not generate innovations exclusively internally, and, second, that no innovation (no product) is purchased (selected) without being tested first. (See Birchenhall, Kastrinos, Metcalfe 1997: 379)

- An evolutionary model of technological change has to name not only the mechanism of variation and selection but also a mechanism responsible for the stabilisation of a successful variation. (See, also, Campbell 1969) Anderson and Tushman (1990) see this in the formation of a "*dominant design*."[2] A *dominant design* initiates further standardisation of individual parts and - with a view to the manufacturer of technology - the optimisation of the assembly processes and the stabilisation of manufacturer-supplier relations, distribution networks, and customer relations. From the perspective of the technology user, a *dominant design* reduces the lack of transparency over the variety of products in a given class, and reduces the costs of acquisition. *Learning by doing* and *learning by using* (see Rosenberg 1982) stabilise this design. User experiences lead to an improved understanding of mistakes and permit more reliability through better service. In terms of evolution theory, the successful stabilisation of a technology also changes the selected environment. A technological paradigm now structures further research activities and user needs. It can be suppressed only with great difficulty. This is also why there are dangers of a *lock-in* effect. (See Arthur 1989; 1994; David 1985) For this reason, recent innovation theory also points to further necessary learning strategies for the innovating company, so that it is also equipped to deal with rapid technological change in its environment. Such learning strategies concern the levels of the organisation (*organisational learning*) and the inter-company, inter-organisational levels (*recursive learning processes*, see Krohn 1997). As we shall see below, this extension has important ties with the sociological approach of techno-genesis and network theory.
- Based on the "*evolution metaphor*," *evolutionary economics* has recently developed a variety of analytical and methodological refinements to the design of the theory.[3] *Evolutionary* or *genetic algorithms* play a particularly important role here. The instrument of *genetic algorithms* borrowed from computer simulation (for a basic discussion, see Holland 1992; Goldberg 1989) should be used to develop optimisation procedures whose (modified) functions correspond to those of natural evolution. In particular, computer simulations should model the interplay between variation, mutation, and selection. In addition, the importance of learning is seen and models of learning through imitation are developed. To improve the modelling of imitation learning within a population, some authors replace the selection operator though another operator that they call *selective transfer*.[4] They then relate this modified *genetic algorithm* to the selection of technologies in order to construct a model of technological change. (See Birchenhall et al. 1997: 388ff.) The significant aspect is that the discrimination between the unit of selection and the selecting environment found in biological evolution is abandoned in favour of a discrimination between internal and external selection (379).

Whereas the main contribution of *evolutionary economics* has been to improve our understanding of macro- and meso-structural developments, the micro-sociological analysis of *technology studies* concentrates on the individual innovation processes and delivers know-ledge on the structure and dynamic of the relevant social interaction processes. Among other aspects, it is asking which visions of use and guiding principles are pursued or ruled out, whether and how these are reinterpreted and transformed during the course of developing a technology, how controversies between different functional demands and efficiency criteria are resolved, which micro-political constellations are decisive in shaping a technology, and which organisational and institutional conditions exert an influence on this. (See Rammert 1993; Rammert, Bechmann 1994; Halfmann et al. 1995) It has shown that assumptions regarding the possibility of controlling and planning technological change are inappropriate. Deterministic assumptions over one best way of technological progress are rejected successfully and replaced by the *social construction* of technology.[5] It reveals that actor configurations, the poly-contextuality of the decision-making criteria, and the contingency of the decision-making process are characteristics of the innovation process and not, as often claimed in classic, more historically oriented technology studies, scientific progress and technological rationality.

Within this research program three lines of development can be distinguished:

- *System approach to technology*: Starting point is the assumption that modern technologies are systems "*of interlocking and functionally interrelated chains and hierarchies of artefacts*" (Rammert 1982: 34). Many of the case studies in this field by Hughes (1983), and Mayntz, Hughes (1988) as well as those from Perrow (1984) and La Porte (1988) focus not only on technological components but also on social artefacts like organisations, institutions, and professions, i.e. banks, laws, and engineers. Hughes (1987) concentrates on *system builder* who are not only the inventor of the basic technology but also the builder of the whole organisation in which the invention is imbedded for its use. This makes clear that there is a strong connection between technology and social organisations. The discovery of a strong link between technology and organisation was directive for a sociological oriented innovation research. The picture of the *lonesome inventor* could be refused and a more realistic view about the strong connection between social and technological components (*seamless web*) became visible. On the other side it was not possible to demonstrate the peculiarity of the act of invention (*technology push*) nor to demonstrate the decisive role of the environment with respect to innovation dynamics. A systematic connection between the development of technology and its application context was only possible within the new research on techno-genesis.
- *Techno-genesis-studies*: Although directed initially only toward generating new technologies, the application context of these new technologies has been discovered as a determining factor and has been increasingly taken into account into this research field since the beginning of the 1990s. Through the further consideration of institutional and organisational parameters within research on technology production, attention has also spread to the constitutional conditions and functional mechanisms of innovation processes. Techno-genesis-studies on industrial innovations are available in the field of machine tool industry (Kowol, Krohn 1997), the waste-disposal industry (Herbold 1995), automobile industry (Knie 1994), computer- airbus- and high-speed-railway-industry (Weyer et al. 1997), and software development (Degele 1996; Konrad, Paul 1999). Although the research strategies and the theoretical orientation differ within these studies there is one in common: There is a paradigm shift within the explanation of technological change from a technological

rationality towards a actor oriented perspective. It can be stated that technological development is not a linear-sequential process that can be traced back to rational decisions. Within the framework of research on technology production, the innovation concept describes the construction of an application context through a *recursive process* of transforming scientific and technological basic knowledge and anticipated visions of use, of institutional decisions and cultural models, practical experiences with the development of a technology, the commercial, market-oriented considerations, and, not least, the transformation of interests and utopias in order to shape the future into new marketable products and procedures that, in turn (may), trigger numerous learning processes and feedback permeating as far back as the basic science. These lines of development within the techno-genesis-studies can be understood as a forerunner of the new paradigm on network analysis.

- *Network analysis:* As future-related projects, innovations processes are always fraught with uncertainty, contingency, and acceptance. They contain assumptions about future applications and uses. They model a social-technological application context in which the technological ideas are developed and, later, the artefacts are implemented *experimentally*. Modern innovation processes couple the technology developers' visions of use with the applied practice of users. The observation of these social closure processes between the generation, application, and regulation of innovations has led to a new way of modelling innovation dynamics: the model of *innovation networks*. The figure of the recursive coupling of visions of use (intentions) and applied practice (expectations) in the innovation process forms the starting point in modelling theory for the recent, network-like analyses of innovation dynamics. (Kowol, Krohn 1995, 1997; Rammert 1997; Weyer 2000) At the moment there are major differences between individual network approaches. These differences mainly exist with respect to explanations about the foundation of networks and the theoretical understanding of their peculiarity. But there is also disagreement within the theoretical understanding of the role of boundaries and the role of social mechanisms like trust, reciprocity, learning, power, and regulation of conflicts with respect to the co-ordination of network activities.

Despite of all the empirical evidence of the existence of innovation networks and its phenomenological descriptions it is still an open question, how individual actors are going to co-operate within a new form of organisation which gains its own identity. In line with recent ideas in self-organisation theory, the process of networking heterogeneous (individual or collective) actors can be described as a process of dynamic structure formation. Such processes lead to a circular, autonomous form of operation that hardly ever tolerates external control. It is unlikely that a dominant (controlling) actor will run a network. Therefore the dynamics becomes complex, rules of co-operation emerge and external control must be replaced by self-control. The various conceptions of the "*innovation in the net*" (Rammert 1997) thus counter the biology-laden basic scheme of (technological) variation and (market) selection found in *evolutionary economics* with an alternative basic model. When formulating a theory of innovation dynamics, it would appear to be meaningful to abstract from biological evolution and seek a new reference point. This also seems worthwhile because modern biology and genetics have passed beyond the foundations of Darwinism, and there is a broad acceptance of concepts of self-organisation. (See, for an overview, Foster 2000: 313ff.) As long as revolutionary changes are disregarded, new technologies (innovations) can certainly be viewed as variations of existing ones. However, they do not vary *blindly*, because they have an application context that has already been anticipated in the draft of the construction. Nonetheless, the impact of this application context is, primarily, not *selective* but *constructive*, and it has an accelerating impact through positive and negative feedback. Unlike *evolutionary economics* or biological evolution theory, cyclical couplings between variation and selection are assumed in the case of innovations.

"*The most important point in modelling theory is that the structuring of need is a matter for the technological draft. It is precisely here that we find the feedback between technological variation and need variation. The reciprocal coupling between variation of needs and technological variation through which the model achieves its cyclicity is already available in any case in the sense of the demand model. Such a non-linear process dynamic also departs from the constraints of classic Darwinism, because its basic formula of blind or randomly determined variation coupled with a systematically effective selection is no longer applicable when there is no way to distinguish exactly between variation and selection.*" (Kowol 1998: 24; see also Krohn, Küppers 1989 ;)

The new approach of self-organising innovation networks proposing an integrated theoretical framework. It takes into account concepts of self-organisation that reflect the parallel operation of a great variety of forces from formerly separate social spheres on the innovation process and provides a better understanding of knowledge production and innovation. It covers micro-aspects (such as actor strategies and networks) but also the context and institutional conditions of innovation dynamics.

3. SELF-ORGANISATION: THE REDUCTION OF UNCERTAINTY WITHIN COMPLEX SYSTEMS

There is no doubt: innovations are becoming more complex but not only because it consists of various parts, but, at most, because it integrates the dynamics of these parts and unifies them in a function. However, modern technologies do not just have to integrate technical appliances into a function. They also have to meet economic, political, and social demands. In all, today's new products have to:

- *Be economically viable.* In other words, it has to be possible to develop and produce them with the available commercial resources. They have to be able to assert themselves on the market and they also have to make a profit.
- *Be technologically feasible.* This means they have to function in technological terms while simultaneously being safe and reliable.
- *Fit the political landscape.* In other words, they must not contravene existing environmental and safety standards.
- *Be accepted by customers.* This means they must fit into a real application context.

Because these functions cannot be met independently from each other, innovations become increasingly more complex. Changes to comply with technological safety may pose a risk to economic viability, new environmental standards may endanger technological functionality, and technological specifications may threaten customer acceptance.[6] Moreover, because of the functional unity, the whole cannot be broken down into its component problems and partial solutions cannot be integrated into a new product. Exactly this is the reason why the concept of complexity has become a decisive characteristic of modern innovations which requires the integration of different forms of competence for its production. Self-organising innovation networks are the adequate measure to reduce the complex dynamics of innovation processes. They allow the integration of diverging interests and the use of different knowledge bases.

The question that emerges in relation to innovation networks is how do heterogeneous (individual or collective) actors form a network with its own autonomous way of operating that distinguishes itself from the environment and is broadly resistant to forms of external control without the rules for this "*momentum*" being given externally. A formally satisfying, model-like answer to this question on the emergence of global structures from local interactions became possible in the early 1960s. First concepts of self-organisation have been developed. From a broad field of examples from the natural sciences the following generalisations can be drawn:

- The driving force of self-organisation is a given "*non-equilibrium*", which is kept up by external resources from compensation towards equilibrium. This term non-equilibrium is used to describe a configuration in completely general terms where a situation sets a dynamic in motion that "*reduces*" the non-equilibrium, in other words, that strives toward compensation and makes this non-equilibrium disappear.
- The compensation of a non-equilibrium reacts on the non-equilibrium and modifies it. This differs from the case where on the one hand a "*mechanica*l" force is the cause of a dynamics, on the other hand, that force is not changed by the dynamics caused by it.
- This circular linkage of "*non-equilibrium*" and "*compensation*" in some area leads to the establishment of a circular causal process relationship that makes within this area a differentiation of system (*internal*) and environment (*external*) which can be observed. In this sense the emergence of a system is the result of circular causality.
- If this circular linkage is non-linear, cause ("non-equilibrium") and effect ("compensation") no longer have a unique relationship. It becomes ambiguous, and one type of "non-equilibrium" finds several forms of compensation.
- If a cause generates precisely the effect that reproduces its cause, the dynamic comes to a "stop," and an order with some degree of complexity is established.
- Therefore, the emergence of order is a selection process in which a certain form of dynamic suppresses all others because it is the only one in which its cause is reproduced by it. The selection mechanism of self-organisation is the circular conditional relationship of cause and effect. Circular causality is the mechanism of self-organisation and causes the emergence of order.[7]

A successful application of the concept of self-organisation to the phenomenal domain of the social assumes that one can find social mechanisms exhibiting the form of circular causality. A *social cause* has to produce *social effects* that change their cause. A stable social order can then be understood as a reproduction of a social cause through the social effects that it triggers. The (social) perception of uncertainty and the social activities to reduce it possess such a circular structure, and are therefore proposed as a mechanism of social self-organisation. (See Küppers 1999)

In general, deficits in regulation of social interactions are seen as social uncertainty which asks for regulation: The risk of violence within confrontation and the risk of being cheated within co-operation. The regulation of the societal co-operation thus becomes a permanent topic of social coping with uncertainty, and society becomes a dynamic system. Its self-organisation supposes a specific micro-sociological linkage mechanism: Everybody acts in anticipation of the acts of others while taking into account their own conjectures regarding what others expect of them. The decisive mechanism for the macro-sociological pattern formation is, once again, a feedback between uncertainty (cause) and coping with uncertainty (effect) on the micro-level that leads to the formation of social rules, and after a while, to a consolidation in the form of the institutionalisation of social interaction.

Through the mechanism of "*circular causality*" the social dynamics becomes “*closed*” because (social) causes and their (social) effects change each other. As a consequence a specific form of uncertainty and its regulation began to reproduce each other. A specific social structure has emerged as a “*stationary state*” of the social dynamics, i.e. the perception and regulation of social uncertainties. The emerging social structures consist of action rules that consolidate conservatively into the various institutions of society such as the legal system, business organisations, networks, or political parties. Although the general reservation of contingency, of being able to be other, is retained in principle, it becomes powerless when faced with the conservative power of this institutional arrangement toward which all action has always been oriented in a given society.

The way of dealing with social uncertainty determines the forms of social self-organisation. Individual behaviour is integrated to form social patterns without any need for directives from the environment. Examples of this are the large functional subsystems of society: politics, law, the economy, science, and so forth. They have all emerged as rule systems of social action because they have proved their worth in functional terms: They have reduced the social uncertainty in their own domain through regulations laid down in the specific systems of institutions. Police, public prosecutors, judges, and lawyers investigate, press charges, adjudicate, and defend according to rules that are accepted within a society and that are considered appropriate to guarantee public safety and social justice.

But social uncertainties cannot be transformed into social certainty. Rules (consensus, agreements, contracts, laws, moral obligations) can only reduce them to a socially acceptable form of relative certainty for a limited period of time that dynamic societies may once again use as the starting point for new forms of uncertainty. Therefore, social uncertainty exists, namely, not as an objectively given state of affairs but as something that is constructed through social negotiations. Experience, knowledge, cultural practices, and the like take on an important role. This context opens up a scope for interpretation within which the perception and definition of social uncertainty as well as procedures for dealing with it have to be negotiated socially. Processes of social self-organisation deliver the selection mechanisms to which such negotiation processes are subjected. They replace the classical idea of an objectively given rationality lying in the nature of things that permits an unequivocal definition of and an appropriate way of dealing with uncertainty. This socially constructed aspect of risk was long overlooked in the political discussion on technological risks in, for example, the controversy over nuclear energy. Nowadays, the "*nature of the thing*" proves to be, itself, a social construction that can be maintained only as long as the belief in the "*mechanistic world view*" seems to be justified through the successes of modern science.

Because of this circularity of its dynamics, self-organising systems cannot be controlled directly by their environments. They do not react directly to changes in the environment, but always in line with their eigen-dynamic. Although, even in simple non-linear systems, a pattern formation can be provoked through impulses from the control parameters, this cannot determine the pattern itself. Unlike the control switch on a machine, control can be built up only through knowledge of the eigen-dynamic of the organism and the existence of a structural relation between the environmental stimulus and reaction generated through feedback. This has far reaching consequences: In the case of psychic systems for instance, *learning* is possible only if the learner offers the teacher a selection of different patterns of behaviour based on his or her eigen-dynamic so that the teacher may choose one and stabilise it through reinforcement mechanisms.

This is why self-organising systems are also called *operationally closed*. The term should emphasise that all causes for changes to the state of the system are exclusively consequences of system-internal operations. This operational closure does not contradict the openness to resources of dynamic systems. It is far more the case that the difference between open and closed exists on two different levels. Thermodynamically, the difference is that between isolation and exchange with the environment - in this sense, dynamic systems are open. Cybernetically, in contrast, the open/closed difference is used in another way, and systems are open if they do not possess feedback, that is, if their output does not become the input of a control loop. Closed systems, in contrast, are feedback systems with closed loops. Negative feedback is self-regulating; positive feedback generates system changes. In *linear* cases, these are processes of growth and shrinkage processes; in *non-linear* cases, new system states through instabilities (reinforcements of deviation).[8] Hence, self-organising systems are thermodynamically open and, cybernetically, closed[9]. They are "*historical*." Their behaviour in the present is determined by the past.

The mechanism of operational closure is simultaneously the mechanism for excluding an environment. In both operational and spatial terms, it defines a border marking the separation between system and environment. Systems are now no longer entities that an observer with specific epistemological interests has isolated from a total context, but process networks that separate themselves from the environment. Self-organising systems are, in this sense, *real* systems.

The self-organisation of the system occurs within its borders. This guarantees the system's identity even when structures change. Although organisation (circular causality) and structure determine each other, the conditional relationship can take different patterns. When organisation - and thereby, identity - remains constant, systems can adapt to a changed environment through structural changes. Adaptation is an achievement of self-organisation and not the outcome of selection through an environment.

4. SELF-ORGANISING INNOVATION NETWORKS

Complexity is the main characteristics of modern innovations. In most of the products an increasing number of parts is integrated into a single function. At the same time a product has to fit into the market, i.e. to fulfil specific requirements of a potential user. "*This complexity has meant that multidisciplinary knowledge has become necessary for the generation and development of new products. In the computer industry, for example, the disciplines involved in the innovation process may range from solid state physics to mathematics, and from language theory to management science.*" (Malerba 1992)

But it is not only this “*multi-*“or “*trans-disciplinarity*” which makes that innovations are products that are burdened with uncertainty. Generally speaking, there is a lack of knowledge on how to transfer even a known technology into a new usage context. Although the underlying effects are known, nothing is known about how they will behave in the planned application context. One example is that even though a lot is known about the physics of fusion processes, the construction of a fusion reactor would be a long-lasting and expensive enterprise. Indeed, throughout the world, research teams have been trying to produce the necessary knowledge for more than 40 years. Although this is an extreme case, it illustrates the knowledge uncertainties that may be linked to the use of still existing knowledge within the context of a new technology.

When the technology and/or its application context is new, there are no databanks, no experts whose knowledge can be drawn on. This knowledge first has to be developed. Knowledge production becomes one of the main activities of innovation networks. The starting point for the production of new knowledge are hypotheses formulated on the basis of available knowledge. These hypotheses prove to be either right or wrong when tested on a prototype, in a market analysis, or a customer survey. If a hypothesis is not confirmed, it is modified and re-tested. This testing is itself a complex process, because it is not simply a case of comparing data with hypotheses. Instead - once again, with the aid of knowledge - a decision is made on how far the chosen procedures are appropriate for testing the hypotheses, and in what way the data have to be interpreted in order to confirm them. (See Küppers 1999) In this sense, knowledge production is a process in which a hypotheses and the data they generate determine each other and this “structure” is seen as a new piece of knowledge that is believed to be certain.

Knowledge is the resource to reduce the “technical” dimension of complexity of the final product. Another dimension of complexity is the social organisation of its production, i.e. the organisation of collaboration between different competencies since the construction of an innovation requires more and more intellectual, social, and material resources than are generally available to a single company. “*So-called go-it-alone strategies or conservative strategies which mean that a firm relies only on its own R&D endeavours, cannot be successful in such a complex environment. Because of the systemic character of present-day technological solutions, technological development necessarily becomes a complex interactive process involving many different ideas, and their specific interrelationships.*” (Pyka, Saviotti 2000: 13).

Companies therefore have to co-operate with other companies in order to gain access to the resources they lack. In many cases, they also have to co-operate with non-business institutions. These are mostly research centres at universities and government laboratories as well as the state-run and non-state-run institutions that regulate and license new technologies. This is because innovations must not only function technologically and be economically viable, but also fit into the socio-political environment. In the innovation networks built up over such co-operative relationships, resources necessary for the success of the innovation process can be deployed: theoretical and practical *knowledge* as a precondition for the development and implementation of innovations, *social competence* for the successful organisation of co-operation in the network, and the necessary *financial means* to pay for it all.

Therefore, in innovation networks discursive negotiations with the aim to reduce the uncertainty of the innovation process with respect to its different dimensions serve as a co-ordinating mechanism. This differs from the formal contracts that dominate market co-ordination, as well as from the principle that instructions co-ordinate social interaction within hierarchical organisations. (See Kowol, Krohn 1995) Therefore, innovation networks differ from classical organisations in terms of their structure and dynamics. Although they can be set up as the outcome of contractual regulations between the co-operating institutions, their internal form of operation is neither regulated contractually nor determined by management directives. Innovation networks operate according to the principles of self-organisation. The element that triggers their emergence or establishment is the idea that the uncertainty makings the development of innovations a risky venture as a result of increasing complexity can be reduced by co-operating with suitable partners.

This approach to innovation makes *innovation networks* responsible for reducing the complexity by subjecting the co-operative draft of an innovation to appropriate eligibility tests in various phases of recursive learning processes. The generation, application, and regulation of new technologies are therefore not coupled in the sense of a trial-and-error procedure of variation and selection, but through a constructive knowledge production and learning process that is co-ordinated between the actors engaged with the aim to reduce the uncertainty accompanying complexity. Therefore, these knowledge production and learning processes are directed toward the *management of uncertainty*. The number of actors involved is determined by the uncertainty dimensions affected by the innovation: time frames, technological complexity, financing arrangements, knowledge deficits, the legal situation, risk perception, public sensitivities, and so forth. But new problems arise. Why should individual and collective actors enter into network-like relationships?

The general answer is that individual actors foresee a potential gain through co-operation that cannot be attained through an individual strategy for maximising utility. The basic hypothesis is that *alter* controls resources (capital, man power, knowledge, experience etc.) that *ego* needs to increase utility and vice versa. (See Kowol, Krohn 2000)

This *trust* in the reciprocal utility of co-operation is the integrating force within the network. As a rule, it is stronger than the *fear* of being disappointed and deceived by one's partners. Building up this trust and overcoming the fear are preconditions for the emergence of a network and determine its dynamics.

Innovation networks reduce different kind uncertainties in the innovation process with respect to its technological, social and economical dimensions. This calls for the integration of various competencies. Which competence is relevant is not certain from the outset. It is only during the course of the innovation process that the areas in which knowledge is uncertain become apparent. Therefore, as a rule, innovation processes are dynamic, in other words, they modify their co-operative relationships over the course of time. This does not mean that membership in a network cannot be regulated through contracts or job delegation. However, the network itself decides which members are involved in which forms of co-operation. Innovation networks are determined through their operations - the production of knowledge, the integration of diverging interests - and not through formal memberships. Although they may influence the operation as marginal conditions, they cannot finally determine it.[10]

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Beside the problem of social integration knowledge production in innovation networks reveals the characteristic features of self-organisation: circular causality, autonomy, and self-reference. Knowledge uncertainty is reduced, in other words, modified through knowledge, and the modified knowledge uncertainties require new knowledge for their reduction. At the end, the network comes to the judgement that is knows everything it needs to know, it possesses all the knowledge, and can implement it in a new product or process. As a result, innovation is generally not an artefact, but a recipe for its manufacture. It covers technological details, the conception of exploitation contexts, and extrapolations over the commercial success.

In this sense, the production of new technologies is no longer a process of trial and error involving variation and selection but, rather, a co-ordinated process of knowledge production and *recursive learning*. This process involves actors such as suppliers, banks, universities, research institutes and governmental regulatory bodies. The number of actors involved is determined by several dimensions of uncertainty associated with innovations: timeframes, technological complexity, modalities of financing, deficits in knowledge, legal issues, risks, and public sensitivity. (See for instance: Daele, Krohn 1998; Braczyk, Cooke, Heidenreich 1998)

Summarising, the formation of new innovation regimes will depend increasingly on whether, and to what extent, actors are able to construct flexible networks that exploit the advantages of co-operation and banish the disadvantages of rigid organisations and turbulent markets.

Nonetheless, it also has to be taken into account that co-ordination and co-operation based on trust do not always have to succeed. Problems not only with emerging threats of opportunism but also with knowledge transfer blockades and blockades due to professional cultures generate potential barriers that are not easy to manage. Finally, problems with *divided loyalties* may well prove to be the special Achilles' heel of innovation networks: Network actors have to be loyal not only to their network but also to their focal organisations. The fragile structure of a network will be threatened when different expectations and interests between the network and the focal organisations emerge as a problem of twofold commitment, and actors are confronted with contradictory demands. Finally, it should also be mentioned that innovation networks are able to generate externalities that have hardly ever been described theoretically up to now.

5. UNDERSTANDING THE CURRENT AI TECHNOLOGY

Artificial Intelligence (AI) has made significant advancements in recent years, and it has become an increasingly important aspect of many industries, including healthcare, finance, retail, and transportation. The current AI technology can be broadly classified into two categories: narrow AI and general AI. Narrow AI is designed to perform specific tasks, such as image recognition or voice recognition, while general AI has the capability to perform a wide range of tasks, just like a human being. Currently, most AI applications in use are narrow AI.

One of the most significant developments in AI technology is deep learning and neural networks. These algorithms are inspired by the structure and function of the human brain, and they have made remarkable progress in tasks such as image classification and language translation. Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are two popular types of deep learning algorithms used for computer vision and natural language processing respectively.

Another important area of AI technology is computer vision, which involves using AI algorithms to interpret and understand visual information, such as images and videos. Image recognition, object detection, and image segmentation are some of the applications of computer vision. These algorithms can be used in various industries, such as retail and e-commerce, where they can be used to automatically categorize products, detect fraud, and recommend products to customers. (Christopher Collins, 2021)

Natural language processing (NLP) is another significant area of AI technology, and it involves using AI algorithms to understand and generate human language. NLP algorithms are used in various applications, such as sentiment analysis, text classification, and machine translation. With the help of NLP, machines can understand and respond to human language, making it possible for humans to interact with computers in a more natural and intuitive way.

Reinforcement learning is an AI technology that is used to train machines to make decisions by continuously learning from their environment. In reinforcement learning, an AI agent learns to maximize its reward by taking a series of actions in an environment. This technology has applications in various industries, such as gaming, finance, and robotics.

Explainable AI (XAI) is an area of AI technology that focuses on making AI algorithms more transparent and interpretable. XAI is important because it can help reduce the risk of AI algorithms making decisions that are not explainable or fair. XAI algorithms provide insights into how AI algorithms make decisions, which can help ensure that the decisions are ethical and fair.

Transfer learning is a technique used in AI to leverage knowledge from pre-trained models to solve new tasks. This can save time and resources, as the pre-trained models have already learned a lot of relevant information. Transfer learning is commonly used in computer vision and NLP.

Unsupervised and semi-supervised learning are two types of machine learning algorithms that do not require labelled data to learn. Unsupervised learning involves training the model on unstructured or unlabelled data, while semi-supervised learning involves training the model on a combination of labelled and unlabelled data. These algorithms can be used to learn patterns in data, and they have applications in various industries, such as finance and healthcare. (Loukas, 2020)

In simplest of the terms it is the subject in computer science which is making our robots, computers to think like the homo-sapiens. In conclusion, AI technology has made significant progress in recent years, and it has a wide range of applications in various industries. (Agarwal, 2013)

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