How Strategic Orientation Affects Inter-Organizational Networks in Uncertain Environment

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***Abstract*- This article deals with business network and cluster dynamics, as well as inter-firm joint-ventures and collaborations, in order to study their evolution and possible effects when radical innovation occurs inside them. Each network transformation is brought about by specific combination of changes in tie creation, tie deletion and power inside the network. In the present work an agent based model is introduced (E³), which aims to explore how innovation diffusion can facilitate network formation of existing enterprises, affect network topology (e.g. an enterprise owning an innovative process could become a focal point), induce new players to enter the market and spread onto the network by being shared or internally acquired by new players.**

In order to study these dynamics, with regards to the optimal balancing among different strategies and the importance of exogenous parameters in cluster creation, a model is presented. It follows the agent based paradigm, particularly suited for describing complex social systems in which many parts interact among them. This allows creating simulations of the analyzed system and testing different hypothesis. Besides, it's a paradigm in which the emergent features of complex systems can arise spontaneously, thanks to the bottom-up design. A model is introduced and described in detail.

Qualitative results supported by an empirical case study are described, reflecting current state-of-the art theories. The results show how clusters emerge and evolve among enterprises, and how radical innovation can trigger this phenomenon.

Keywords- Network Dynamic; Radical Innovation; Innovation Diffusion; Agent Based Model

I. INTRODUCTION

. Even if the network model is not a recent strategic discovery, the increasing cost and complexity of the R&D, the shortening of the technology life cycle, the improvement of the ICT technology and the increase of the competition and uncertainty inside the industry, drive the organization toward a network model where the partner selection and management of the relation become important strategic variables. The early Schumpeterian model of the lone entrepreneur bringing innovations to markets has been superseded by a rich picture of different actors working together in iterative processes of trial and error to bring about the successful commercial exploitation of a new idea [62, 60, 74, 20, 67]. As many author underlined [12] being inside a network is not enough if the organization is not able to perceive the business opportunities of the environment, exploit the network potentiality to increase its strategic capability to enhance its strategic advantage.

Although the analysis of the network, seen as a support for the organization to create and diffuse innovation, has received most attention, less attention will be devoted to the impact of the innovation diffusion on the network structure. What kind of changes might occur in a network when an innovation starts to circulate? And which are the variables that can accelerate these network modifications? The organization that perceive the network changes before and better than the other, get a significant advantage in term of network and industry setting?

Assuming that the decision to adopt a new innovation is not a choice between adopting it or not but an option between adopting now or deferring the decision until later and taking for granted the S-shape model -where the adoption proceed slowly at first, accelerates as it spread throughout the potential adopting organization and slow down as the organization become saturate, we prefer to concentrate our effort only on the impact of technological innovation diffusion on network.

Moreover, network changes are path dependent within the organization's intrinsic characteristics - like managerial attention and strategic actions - and they introduce more complexity to the relationship between innovation diffusion and network modifications [42]. Corporate manager faces several difficult in deciding whether adopt or not a new innovation which have some elements of conventional investment activities but for which severe uncertainty means that continuous feedback from other adopters, market and industry reaction are essential

In fact, the inability to predict future innovations as well as the organizations' and costumers' reactions and rewards add more complexity to the network framework. The recent experience of inaccurate forecast of the mobile phone potential market for various generations and various functions associated with it (the unexpected success of text messaging, for instance) is equally instructive. The activities employed by organizations to cope with and reduce uncertainty influence the selection of their partners and the relation with them, building network changes assumptions.

We decided to consider only the impact of radical technological innovation on inter-organizational network.

Even though different level of network analysis existed and are important to the innovation creation and/or diffusion (intra-organizational, firm level, dyad level, inter-organizational level, regional or national) we decide to narrow our approach on the inter-organizational level. The inter-organizational networks provide a durable structure for inter-firms relation and force the organization to integrate its external relation into a coherent strategy and manage them over the time. Thus the changes occurred at the inter-organizational network level massively impact on the organization changing the organizational process (resource access and different processes such as R&D, production and commercialization process), strategic activity (objective definition, strategic action) and the long run performance and vice-versa [47].

We decide to focus our analysis on the radical technological innovation diffusion defined the technological innovation as tools, devices and knowledge that mediate between inputs and outputs (process technology) and/or that create new products or services (product technology) [59, 69]. The study of the radical innovation defined as a dramatically change in the organization business model and in the industry better underlined the difficulties faced by the organization to grab of the opportunities opened by revolutionary technological changes. Examples include the organizational consequences of changes in product architectures [32], resistance for groups with established competencies [68], the unexpected emergence of new markets [13, 44]. Moreover technical advance often precedes managerial, organizational and in general business model innovation, because, as Pavitt [52] sustained, it may be practically impossible for a firm that wishes to remain competitive to resist making use of new technologies and knowledge in its future product or process development, unless it wishes to become a niche producer. Our work focuses on understanding what happen when a radical technology innovation starts to circulate into a network: will the network change in term of alliance activities? Are the managerial attention and the strategic action important in the network modifications?

To reach our objectives, after a literature overview on we will test our hypothesis use an Agent-based computational models apply on the diffusion of the 3 D printer inside the manufacturing network. We will test what effect managerial attention and strategic actions have on network changes as a result of innovation diffusion using an agent based simulation of 3D printing diffusion in the manufacturing network. The simulation shows how different degrees of the two moderated variables can produce different network changes.

II. THEORY AND HYPOTHESIS

A. *The Patterns of Network Change*

While the network structure is not a fixed set of relationships and partners, it evolves in time driven by endogenous or exogenous environmental changes. In the former, variables such as organization relational activities have an important impact on network structures and, at the same time, the previous network structure can influence the organization relational strategy in an endogenous path dependent evolution [27]. In the latter - an exogenous shock-like a radical technology innovation diffusion [2, 23] - increasing the level of uncertainty inside the industry - can lead to major restructuring such as the creation of new networks [6] and/ or structural changes of the existing ones [39, 40].

Two streams of network changes are relevant for our analysis:

1. Network reinforcement: network reinforcement is characterized by a strengthening of the actor's links and power. If the uncertainty is absorbed by the more central actors, the existing structure will be reinforced and the organization will adapt to the environment improving their existing relations. Network reinforcement could imply that a network actor may combine a low perception of the innovation uncertainty degree with a strategic action aimed at exploiting the existing business model.

2. Network change. Network change is characterized by a loss of prevailing organization power and an increase in the power of the early adopter able to understand the importance of innovation and create new links to cope with the uncertainty and develop a new competitive advantage. Network change could imply a high perception of uncertainty where the innovation diffusion breaks the rule of the industry impacting on the core business of the organization and on the competition of the industry. The reshuffle of the network, which can occur thanks to the organization's strategic actions more devoted to exploring new channels of information and resources, sets the business on new technological trajectories.

B. *Radical Innovation and Alliance Activities*

When innovation starts circulating into the network, the firm's environmental uncertainty increases, amplifying the organization's inability to assess the external environment, future changes that might occur in that environment [56] and which might be the effect, the response and the consequence of the response on the organization [49]. But, whereas some authors argue that new alliances are used to reinforce a firm's relationship with existing partners during uncertainty [25, 43], other authors, such as Kogut [38], find that firms might create new alliances with new partners to cope with the uncertainty expanding their number of strategic options. Anyway, whether the innovation diffusion carry on a reinforcement of the previous links or the creation of new ones the need for new knowledge and source push the organization to increase its alliance activities [56]. Alliance activities are characterized by the creation, deletion or reinforcement of the organization ties. While some authors have emphasized how having multiple type of links represent an important access to different sources and knowledge for the organization, increasing its innovativeness compared to the organization engaged in a single type of ties [57, 3], other researchers have focused their attention on the difference among links. Strength ties – or local link - are links where the new partners are found through an actors' existing network (ego network) or is already known to other partners while weak link (or distant link) implies that new linkages are created with partners whom are not know to the existing partners of an actor. The

Local ties are drivers to reinforce firm's social capital, to decrease the risk hidden in the new partner formation process [55, 14] and to compose dense clique of actors. Granovetter [26] sort out a differentiation between local ties in a dense cliques (strong tie) and the distant tie that bridge these cliques (weak tie), showed the importance of weak links to provide access to new source of information and favourable strategy negotiation position which improve the firm's position in the network and in the industry.

As technological uncertainty is introduced, changes in interaction patterns may occur. As Galbraith [22] proposed and research findings substantiate, increased uncertainty results in increased communication [73, 37], and consequentially in increased alliance activities. Network researchers have followed two different stream in the analysis of the environmental uncertainty impact on network ties: from one side the literature investigated how the increase of uncertainty boosts the array of opportunity inside the industry working as a receptacle of actors. This process will possibly increase actors heterogeneity and ancillary the linkages and interaction among the organization [17]. Basically firms cope with the increase of uncertainty by forming linkages with other organizations that can provide them with critical resources necessary to compete in the new environment (as Pfeffer & Salancik explained in their seminal work on the resource dependence theory [54]). In this way the organization will reduce risks due to unpredictable future evolution through risk sharing alliances, improve its new resource source domain [38, 76] and preserve its flexibility through alliance.

From other side, network researcher investigated how the increase of uncertainty would reinforce the previous links with exiting partner [25, 43]. In this case, firms react to the uncertainty strengthen their ties, since strong ties are likely to be great assistance in times of change and uncertainty. The reinforcement of the existing relation facilitate the adaptation to the environment [72] through an improvement in the information flow [26] and in the problem solving arrangement and raise barrier for the newcomers. The reinforcement of the existing relation can bring the organization to an over embeddedness where network become closed to external information and starts having access to only redundant information leading to the stifling of innovation [72].

As Koka [39] underlined new tie with new partners can mean a radical change in the structure of the network, whereas more tie with existing partners may mean reinforcement of the existing network structure. How the innovation diffusion impact on the network tie creation and or deletion can be hinted by some factors related to industry, general level of uncertainty in the environment, and organization features.

When the innovation starts to circulate into the network, the increase of uncertainty perceived by the actors increase the alliance activities toward who might reduce the uncertainty for itself and others [33, 53, 70], or rather the early adopters.

The early adopters will decrease the uncertainty on innovation improving their knowledge, skill and capability the innovation management: this process will increase their identification as experts by other member of the network [11] and will reduce the uncertainty for the member who will link with them. Contextually with the power's increase, the early adopters swap to a more central position inside the network assuming the role of central actor inside the network. Network centrality brings a better exploitation of new opportunities, influencing the innovation diffusion, attract more new partners, pool more resources to enhance innovation development [65], underlined. As technology innovation is first introduced, their ability to reduce others' uncertainty is expected to be highly nonsubstitutable, since only a few individuals (the early adopters) will be adept at working with the new system [11]. In a positive inner-cycle the early adopter centrality will increase their power inside the network [42] and their reputation [21] becoming a strategic hub of relevant information and resource [46] and a significant partner to be linked with. Early adopter that realise the value of centrality may constantly be attempting to improve their centrality by connecting with more and more central partners and abandon the relationship with partners who are perceived as being less valuable, reducing the latter's centrality.

For what conceived the previous position of the early adopter as it was widely detected the current and future network structure are intertwined: "if uncertainty is absorbed by individuals who were previously less central, their gain in centrality may adjust the overall structure of the organization. Interaction patterns will change as those who were previously peripheral are sought out by others" while "if early adopters are more central than late adopters prior to a technological change, the existing structure will be reinforced" [11].

Hypothesis 1: the uncertainty of innovation diffusion increases the organization's alliance activities with those actors who are able to decrease the level of uncertainty perceived by the organization.

As literature suggested albeit technology provides the opportunity for some actors to increase their centrality and power, there is also a risk that the new technology will not be successful. When the organization's decision is correct, in that it adopts the industry's eventual dominant design, the early adopters will maintain and even strengthen their power and position. When the organization's decision to change technology is wrong (an alternative dominant design emerges in the industry), organizations increases in power and centrality may be temporary and last only until the organization makes the decision to abandon and replace the unsuccessful technology (or, in the extreme case, the firm fails). At this point, a new technology will be mandated, and the process of technological change begins again [11]. .

C. Moderator Variable

The behaviour of the actors inside the network related to the innovation diffusion change according with their perception of the external environment and action implemented to deal the previous perception. Being in a complex social system [24] as the network is, the organization has to develop its ability to perceive the environmental cues react consequentially and in a promptly way.

1) Managerial Attention: the Perception of the Environment:

The organization managers - bombarded by a vast amount of potentially useful information that often exceeds their cognitive capacity [53] - have to select the relevant information ignoring the others [15, 18, 30]. This process of noticing, encoding, interpreting and focusing of environmental issues (problems, opportunity and threats) and answers (proposal, routines, projects, program and procedures)" [51] drives the organization towards its objectives and strategies. What players do depends on the argument they focus on: such focused attention both facilitates perception and action towards those issues and activities being attended to and inhibit perception and action towards those that are not [36]. Managers can focus on internal organization variables developing an internal focus, or they can focus on external organization variables developing an external focus. As managerial attention is a limited capability, those who pay more attention to external variables will have fewer internal analysis resources to turn their attention to, and vice-versa. An internal focus will lead the organization to consider internal resources, process skills and competence as an important set of variables, while external focus will swap the managerial attention to the variables outside the organization boundary, such as environment and external actors. Managers who pay more attention to internal variables are less influenced by industry trends and customer needs and are inspired by internal ideas, resources and processes. In contrast, managers who develop a more external focus are supplementary influenced by competitor activities and industry trends.

The managers that have an external focus better perceive the environmental change and act or react to it, as Milliken suggested [49]. If the organization has an external focus, it's able to detect the radical technological innovation into the network and to react promptly decreasing the degree of uncertainty increasing the number of links. The organization will create new links if the early adopter - or rather the subject pointed out as the expert of the innovation - is out of the network, otherwise it will reinforce the existed link. This process will set off a positive inner cycle: the more links the organization will set up, the more firms will want to link with it.

Hypothesis 2: The external focus is a positive moderator of the organization's alliance activities.

If the organization has an internal focus, it will not be able to perceive a radical innovation diffusion, centring its attention on the internal variable. This process development will bring a negative effect: the less ineffective the organization links to decrease the uncertainty prove to be, the less the network nodes will want to join the organization.

Hypothesis 3: The internal focus is a negative moderator of the organization's alliance activities.

2) Strategic Orientation- the Exploration Orientation:

To deal with the uncertainty and ambiguity of the external environment, managerial attention often reflects the choices of flexibility and stability [9, 10] or in the words of March, "exploration and exploitation". Exploration is associated with terms like search, variation, risk taking, experimentation, discovery, and innovation; while terms like refinement, production, implementation, and execution are associated with exploitation [45] and [57].

Koza and Lewin [41] extend this concept further up to strategic alliances and suggest that those with the purpose of discovering and developing new technologies, including research and development (R&D) alliances and technical alliances, are exploratory in nature, while those with the purpose of making efficient transactions and using resources, including licensing alliances, marketing alliances, and supplying alliances are exploitative in nature. The effort of studying exploration strategy is developed not only from the literature on innovation (e.g. [8]) but also from the literature on the strategic type (e.g. [48]) and information acquisition [45]. For what concerns innovation, the organization that chooses to build up an exploration strategy modifies the usual technological trajectories to develop new or different ones through activities as search, variation, risk taking, experimentation, play, flexibility, discovery, and innovation [47, 4, 5]. As many theoretical perspectives have underlined, the exploration strategy has also an important impact on information acquisition, gaining fresh information to improve rational-choice models returns [58]; collecting information in bounded-rationality models [64]; absorbing of external information in models of learning and innovation [45]; searching for new routines or practices to increase survival likelihood in evolutionary models [50] and developing a market driven management strategy to compete in the open market [7].

The performance related with this kind of strategy are systematically less certain, more remote in time and often negative as March's seminal work underlined: "... The essence of exploration is experimentation with new alternatives... Its returns are uncertain, distant, and often negative" [47]. The higher costs and risks of the exploration are balanced by the possibility to carry on in a dynamic environment improving the firm's ability to adapt to environmental change, reduce the risk of obsolescence and in general create those capabilities necessary to survive and reach long-term prosperity.

The more competitive and dynamic is the environment, the more the exploration strategies permit to achieve the best performance [71] avoiding the exploitation trap. The more the organization is exploration oriented, the higher is its direction in creating new links with new partners and driving the network toward a new network creation or network change

Hypothesis 4: the Exploration strategy is a positive moderator of the organization's new alliance activities.

The less an organization is exploration oriented, the higher may be the need for keeping existing links with existing partners and driving the network toward a network adaptation.

Hypothesis 5: the Exploitation strategy is a positive moderator for the reinforcement of old alliances.

In the following paragraph we have decided to simulate a case of innovation diffusion analyzing how the network organization can change with external focus exploration or internal focus exploitation.

III. EMPIRICAL EVIDENCE AND SIMULATION

A. *The Third Industrial Revolution: the 3 D Printing Introduction*

Even if the literature on management and design studies dealing with 3D printing manufacturing technology is very scant, this innovation seems to be charming for practitioner and organization in many industries: big companies including Mattel; Medtronic and Boeing of the US; German car group Daimler and the Italian glasses producer Luxottica, is trying out this technology. As Peter Marsh underlined in a recent FT article (5/6/2012):

“The world of manufacturing is being shaped by a new industrial revolution, ...This new period, which started in 2005, features the disciplines of “networked manufacturing”, connecting up design with physical production even when these activities are many miles apart, global “niche” production, where companies make narrow ranges of products but sell them globally, and the rapid transfer of “production intelligence” in the shape of designs, intellectual property and technology”

The running of a 3D printer start from a software technique aimed at helping designers to create shapes of parts in three dimensions on computer screens and then transfer the instructions for making them to production machines. Such software is being used to make products on this basis in a range of industries from aerospace engines to jewellery. Laser scanning systems - made by companies such as the US’s Faro Technologies - can be used to measure the dimensions of items that need to be replicated or modified. Such items could be anything from products or parts made by competitors - in so-called “reverse engineering” - to parts of the human body. The information can then be converted into computer codes and sent to a production machine for turning into a solid object.

The new technologies will change many aspects of the manufacturing industry:

- Change in the relation between design and production. As Abe Reichental (probably the biggest leader for the sector) a 55-year-old Israeli-American who is chief executive of 3D Systems, a US company that with Stratasys is one of the world's two biggest producers of 3D printing machines, says the technology can contribute to the "democratisation of manufacturing" by lowering the barriers between design and production. "3D printing can provide the garage entrepreneur with the same productive capabilities as the large corporation" he says. The designer will have the chance to do not only the scratch but also the prototype of the product or better the final product. This change will permit to the designer to acquire a part of the value chain belong to the manufacturing organization.

- The Increase of the personalization of the product. Akey attribute is that the technology makes it possible to produce "one-off" or highly personalised parts more easily compared to other manufacturing methods. This advantage will impact on the reduction of the relevance of inventory risk and management connected to the opportunity to print on demand the desired artifacts;

- The shortening cycle time. Jeff Immelt, chief executive of General Electric[1], point out the technology's biggest impact in the "shortening cycle times" between designing products and making them. That could help manufacturers in the developed world compensate for higher wage costs compared with those in more emerging economies such as China. Joe Hogan, chief executive of ABB, the Swiss-Swedish engineering group, says: "3D printing means it's possible to go from concept to reality [in making one-off parts] in just a few hours. That's a big help when you are trying to be quicker and more reactive."

- New opportunity creation. Scott Crump, chief executive of Stratasys, sees 3D printing as "part of a spectrum" of manufacturing technologies that are creating new opportunities. These include novel ways to produce the advanced software required to define shapes of products, together with new versions of more conventional cutting tools. As well as selling 3D printing machines, Stratasys also operates factories, including the one in Minneapolis, to use the technology to make parts for customers. It recently announced a merger with Objet, an Israeli maker of 3D printing systems, to create a larger group that will this year have comparable sales to 3D Systems - where the figure is expected to be about $340m.

- Decrease production cost. Hans Langer, chief executive of Eos, a Munich-based company making 3D printers, highlight the potentiality of the 3D printing to "... make items that are lighter, use materials more economically and behave differently to products made today. 3D printing could lead to a completely new way to approach manufacturing," reduced the materials and wastes to produce single product unit.

We analyze the impact of the 3 D printing diffusion on designer’s network, highlighting variables that moderate these effects. We decide to focus our attention on the designer network analysis because as many author suggest (Peter Marsh, 2012) we believed that the designer would be a central actor in this revolution. As the network structure become a key influence both on organization performance and industry evolution, it’s fundamental to understand the network evolution

[1] GE is using 3D printing to make prototype components for testing in its divisions that produce domestic appliances and aerospace engines.

B. Agent Based Model

The Agent Based model constitutes a powerful research method for theory development and is especially well suited to study complex behaviors and systems (e.g., [31]). While empirical analyses are generally data intensive and pose problems for adequately controlling for competing arguments, a simulation permits the creation of an environment, in which the behaviors of organizations are transparent, and can be carefully controlled and modified (see [34], [61], [66]). In this vein, Davis [16] note that even though basic processes, such as competition, imitation, and experimentation, with only vaguely understood longitudinal interactions, are often difficult to analyze empirically, "these processes usually can be computationally represented, verified, and then explored (separately and in interaction) using simulation" (p. 485).

Agent based simulation is an effective paradigm for studying complex systems. It allows the creation of virtual societies, in which each agent can interact with others basing on certain rules. The agents are basic entities, endowed with the capacity of performing certain actions, and with certain variables defining their state. In the model presented here, the agents are reactive, meaning that they simply react to the stimuli coming from the environment and from other agents, without elaborating their own strategies. When the model is formally built and implemented, it can be run by changing a parameter at a time, and emergence of a complex behaviour occurs.

Agent based Modelling is thus one of most interesting and advanced approaches for simulating a complex system: in a social context, the single parts and the whole are often very hard to describe in detail. Besides, there are agent-based formalisms which allow studying the emergence of social behaviour through the creation and study of models, known as artificial societies. Thanks to the ever increasing computational power, it has been possible to use such models to create software, based on intelligent agents, whose aggregate behaviour is complex and difficult to predict, and which can be used in open and distributed systems.

In Franklin and Graesser [19] we read that: "An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future".

Another very general, yet comprehensive definition is provided by Jennings [35]: "…the term [agent] is usually applied to describe self-contained programs which can control their own actions based on their perceptions of their operating environment".

The agents used in this paper are reactive, but organized in the form of a MAS (Multi Agent System), which can be thought of as a group of interacting agents working together or communicating among each other [75]. To maximize the efficiency of the system, each agent must be able to reason about other agents' actions in addition to its own. A dynamic and unpredictable environment creates a need for an agent to employ flexible strategies. The more flexible the strategies however, the more difficult it becomes to predict what the other agents are going to do. For this reason, coordination mechanisms have been developed to ensure that the plans of individual agents do not conflict, while guiding the agents in pursuit of the system goals. Many simulation paradigms exist, agent-based simulation is probably the one that best captures the human factor behind decisions. This is because the model is not organized with explicit equations, but is made up of many different entities with their own behaviour. The macro results emerge naturally through the interaction of these micro behaviours and are often more than the algebraic sum of them. This is why this paradigm is optimal for the purposes of modelling complex systems and of capturing the human factor. The model presented in this paper strictly follows the agent based paradigm and employs reactive agents, as detailed in the following paragraph.

C. The Model

Following the Object Oriented philosophy [1], the model has been engineered and built in Java at the E-business L@B of the University of Turin. While the reactive nature of the agents may seem a limitation, it's indeed a way to track of the aggregate behaviour of a large number of entities acting in the same system at the same time. All the numerical parameters can be decided at the beginning of each simulation (e.g.: number of enterprises, and so on). Everything in the model is seen as an agent; thus we have three kinds of agents: Environment, Enterprises and Emissaries (E^3). This is done since each of them, even the environment, is endowed with some actions to perform.

1) Environment:

This is a meta-agent, representing the environment in which the proper agents act. It's considered an agent itself, since it can perform some actions on the others and on the heat. If features the following properties: a grid (X, Y), i.e.: a lattice in the form of a matrix, containing cells; a dispersion value, i.e.: a real number used to calculate the dissipated heat at each step; the heat threshold under which an enterprise ceases; a value defining the infrastructure level and quality; a threshold over which new enterprises are introduced; a function polling the average heat (of the whole grid). The environment affects the heat dispersion over the grid and, based on the parameter described above, allows new enterprises to join the world.

2) Enterprise:

This is the most important and central type of agent in the model. Its behaviour is based on the reactive paradigm, i.e.: stimulus-reaction. The goal for these agents is that of surviving in the environment (i.e.: never go under the minimum allowed heat threshold). They are endowed with a heat level (energy) that will be consumed when performing actions. They feature a unique ID, a coordinate system (to track their position on the lattice), and a real number identifying the heat they own. The most important feature of the enterprise agent is a matrix identifying which competences (processes) it can dispose of. In the first row, each position of the vector identifies a specific competence, and is equal to 1, if disposed of, or to 0 if lacking. A second row is used to identify internal competences or outsourced ones (in that case, the ID of the lender is memorized). A third row is used to store a value to identify the owned competences developed after a phase of internal exploration, to distinguish them from those possessed from the beginning. Besides, an enterprise can be "settled", or "not settled", meaning that it joined the world, but is still looking for the best position on the territory through its emissary. The enterprise features a wired original behaviour: internally or externally explorative. This is the default behaviour, the one with which an enterprise is born, but it can be changed under certain circumstances. This means that an enterprise can be naturally oriented to internal explorative strategy (preferring to develop new processes internally), but can act the opposite way, if it considers it can be more convenient. Of course, the externally explorative enterprises have a different bias from internally explorative ones, when deciding what strategy to actually take.

Finally, the enterprise keeps track of its collaborators (i.e.: the list of enterprise with whom it is exchanging competencies and making synergies) and has a parameters defining the minimum number of competencies it expects to find, in order to form a joint. The main goal for each enterprise is that of acquiring competences, both through internal (e.g.: research and development) and external exploration (e.g.: forming new links with other enterprises). The enterprises are rewarded with heat based on the number of competences they possess (different, parameterized weights for internal or external ones), that is spread in the surrounding territory, thus slowly evaporating, and is used for internal and external exploration tasks.

3) Emissary:

These are agents that strictly belong to the enterprises, and are to be seen as probes able to move on the competitive arena. If the enterprise chooses to explore externally, an emissary is sent out to find the best possible partners.

While moving, the emissary consumes a quantum of resources, that is directly dependant on the "quality" of the environment. These characteristic simulate the – potential - aversion of leading players to diffusion of innovation.

In the following paragraph a formal insight of the model is given through a set of defining equations, for the agents and the general rules.

D. Model Equations

In order to formally describe the model, a set of equations is described in the following.

The multi agent system at time $\mathbf{T}$ is defined as:

$$\mathbf{MAS_T} = < \bar{\mathbf{E}}, \bar{\mathbf{e}}, \bar{\boldsymbol{\varepsilon}}, \overline{\mathbf{link}} > \quad (1)$$

Where $\bar{\mathbf{E}}$ represents the environment and is formed by a grid $\mathbf{n} * \mathbf{m}$, and a set $\bar{\mathbf{k}}$:

$$\begin{cases} \bar{\mathbf{E}} = < n * m, \bar{\mathbf{k}} > \\ \mathbf{n}, \mathbf{m} > \mathbf{0} \end{cases} \quad (2)$$

Where the set $\bar{\mathbf{k}}$ definines the characteristics of each cell ("heat"), $\bar{\mathbf{e}}$ is the set of enterprises with cohordinates on the grid, and $\bar{\varepsilon}$ is the set of the emissaries, also scattered on the grid:

$$\begin{cases} \bar{\mathbf{k}} = < \mathbf{k_{i,j}} > \\ \bar{\mathbf{e}} = < \mathbf{e_{i',j'}} > \\ \bar{\boldsymbol{\varepsilon}} = < \boldsymbol{\varepsilon}_{\mathbf{i}'',\mathbf{j}''} > \\ \mathbf{0} < i, \mathbf{i}', \mathbf{i}'' \leq \mathbf{n} \\ \mathbf{0} < j, \mathbf{j}', \mathbf{j}'' \leq \mathbf{m} \end{cases} \quad (3)$$

Each enterprise is composed by a vector $\vec{\mathbf{c}}$, and an emissary ($\varepsilon_{\mathbf{e}}$). The vector $\vec{\mathbf{c}}$ defines the owned competences, with a length $\mathbf{L}$ and competences $\mathbf{C_l}$ represented by a boolean variable (where 1 means that the $\mathbf{l^{th}}$ competence is owned, while 0 means that it's lacking):

$$\begin{cases} \mathbf{e_{i,j}} \ni \vec{\mathbf{c}}, \boldsymbol{\varepsilon}_\mathbf{e} \\ \vec{\mathbf{c}} = (\mathbf{L}, \mathbf{C_l}) \\ \mathbf{0} \leq \mathbf{l} \leq \mathbf{L} \\ \mathbf{C_l} = \mathbf{Boolean} \end{cases} \quad (4)$$

In particular, a certain behavior can be successful, meaning that at the end of a phase of internal exploitation or external exploration, a new competence or resource (internal or outsourced, respectively) will be possessed. Otherwise, a it's unsuccessful when, after some steps of research and development (internal exploration) or external market research to find a partner, nothing new is found, and thus the $\mathbf{l^{th}}$ competence remains zero.

$$\begin{cases} \begin{cases} \mathbf{if}\ (\mathbf{b} = \mathbf{success})\ \mathbf{then}\ \mathbf{C_l} = \mathbf{1} \\ \mathbf{else}\ \mathbf{C_l} = \mathbf{0} \end{cases} \\ \mathbf{b} \in \bar{\mathbf{b}} \end{cases} \quad (5)$$

At each time-step the set of links (connecting two enterprises together) is updated basing on the competences of the enterprises.

$$\begin{cases} \overline{\mathbf{link}} = < link\left(\mathbf{e_{i,j}}, \mathbf{e_{i',j'}}\right) > \\ \mathbf{link}\left(\mathbf{e_{i,j}}, \mathbf{e_{i',j'}}\right) = \mathbf{f}\left(\overrightarrow{\mathbf{c_{e_{i,j}}}}, \overrightarrow{\mathbf{c_{e_{i',j'}}}}\right) \end{cases} \quad (6)$$

Specifically, when an enterprise does external exploration, it looks for a good partner, i.e.: an enterprise with a number of competences or resources to share. The strength of the link is directly proportional to the exchanged competences. This set of equations and rules is enough to explore the effects on the network of the behaviors of the enterprises, namely the way in which the firms are managed (externally or internally focused). Though the model allows also to explore the effects on innovation (i.e.: a competence that's possessed only by one enterprise).

In $T = t' > t$ a radical innovation can be metaphorically introduced in the system (this is called "shock mode", since this is decided by the user, at an arbitrary step) by means of increasing the length of the vector of competences of a specific enterprise:

$$\begin{cases} L \leftarrow L+1 \\ C_{l+1}(\boxed{e}) = 1 \\ C_{l+1}(\overline{e} - \boxed{e}) = 0 \end{cases} \quad (7)$$

Meaning that the competence C_{l+1} will be possessed by only one enterprise, at that time, while the same competence will be lacking to all the others; though, all the enterprises' vectors will increase in length, meaning that potentially all of them will be able to internally develop that new competence through R&D, from then on.

The vector length metaphorically represents the complexity of the sector (industry) in which the enterprises operate; an highly technological sector has many more potential competences than a non-technological one. The analysis phase is carried on after several steps after t', in order to see how the introduction of the innovation impacted the network and the enterprise in which the innovation was first introduced. So we have an analysis phase in $T = t'' > t'$ defined as:

$$\begin{cases} MAS'_t \text{ vs } MAS''_t \\ I \rightarrow d\theta link;\ d\theta e; d\theta k \end{cases} \quad (8)$$

Namely, the comparison among the system at time t' and the same system at time t'', since the innovation has differential effects on the number (and nature) of the links and on the number of enterprises, always depending on the managerial behavior of the involved enterprises.

E. Qualitative Results

While the main object of this paper is to present the model itself as a tool for studying the effects of different managerial behaviour (externally or internally focused) on enterprise networks, in this paragraph some insights will be given about preliminary results obtained from the model itself. The presented ones will be mainly qualitative results, although the model can give many quantitative individual and aggregate results. In particular, a "computational only" mode is present in the model, allowing it to perform a multi-run batch execution. The model can give the following different kinds of outputs: 1- a real-time graph, depicting the social network, in which the nodes are the enterprises, whose colour represent the behaviour they are following at a given step, and the links are the ties indicating two or more enterprises mutually exchanging one or more competences. 2- A set of charts, showing in real time some core parameters, namely: number of links (in the network), number of links (average), number of enterprises doing internal exploration, number of ceased enterprises since the beginning, number of born enterprises since the beginning, number of available competences (overall), total number of skills possessed at the beginning, obtained by external exploration, obtained by internal exploration. 3- A real time 2D map, showing emissaries and enterprises.

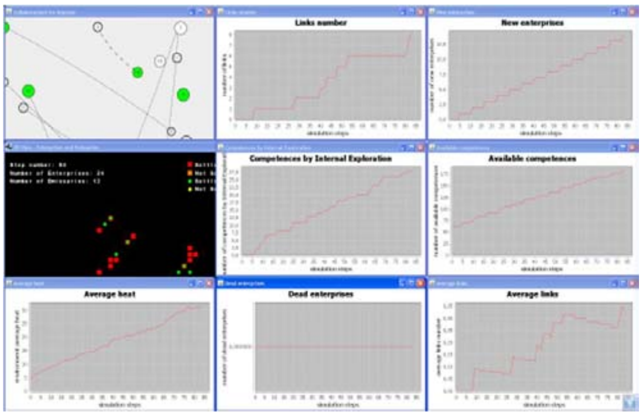

Fig. 1 Graphical output from the model

In Fig. 2, 3 and 4, the output graph is depicted at different stage of adoption of innovation. In Fig. 2 the initial state of the network is shown, where the system features the core of "production" or manufacturing players who, by interpreting the consumers' new needs, achieve new products by obtaining resources and skills from designers and other suppliers. the manufacturing players handle both the prototyping and industrial phases of the product.

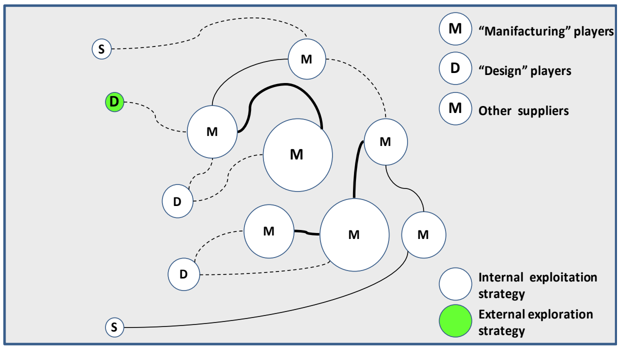

Fig. 2 The system at time 0 (initial scenario)

After the introduction and early adoption of innovation, the network is beginning to change (Fig. 3). The designers and, above all, those who are characterized by the external exploration strategy, change their role from simple sub-contractors to design process organizers. With the new technology they start handling the conceiving phase in its complexity as well as the prototyping phase, thus creating new ties both earlier and later in the value chain.

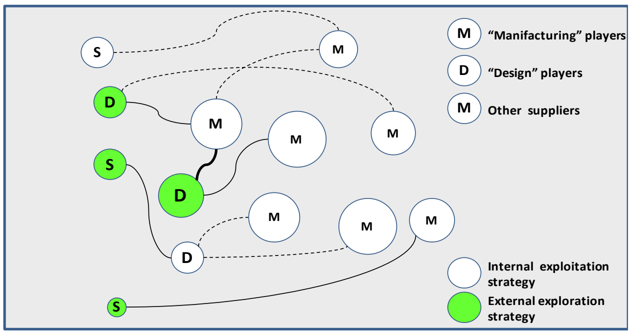

Fig. 3 The system after the introduction and early adoption of innovation

In a final stage, the innovation is widely adopted (Fig. 4). The designers become a central figure in the competitive arena, by taking on a "hub" role they reinforce their ties with both manufacturers and other suppliers who become an integrating part of the design process, from the conceiving to the pre-industrialization phase of the product. The initial ties that characterized the initial scenario are redimensioned or even eliminated and substituted with new collaborations with incumbents and newcomers.

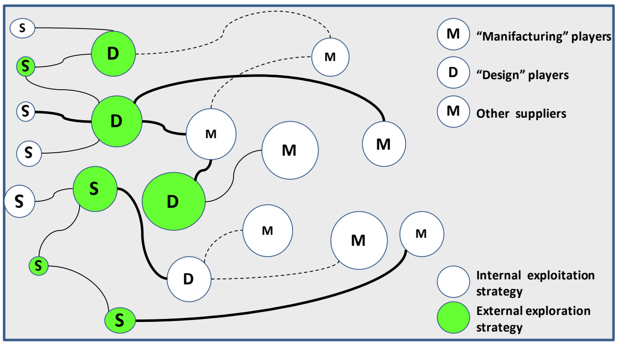

Fig. 4 The system after the widespread adoption of innovation – External explorative strategy

The accomplished simulation shows how the introduction and diffusion of innovation can change the network, and move existing balances. The scenario above shows how players that have an external explorative orientation can obtain a central role and increase their influence within the entire system and stimulate a diffusion of innovation using the right external exploration strategy.

In the following scenarios we have simulated the effects on the network dynamics combining different degree of strategic orientation (Figures 5, 6 and 7).

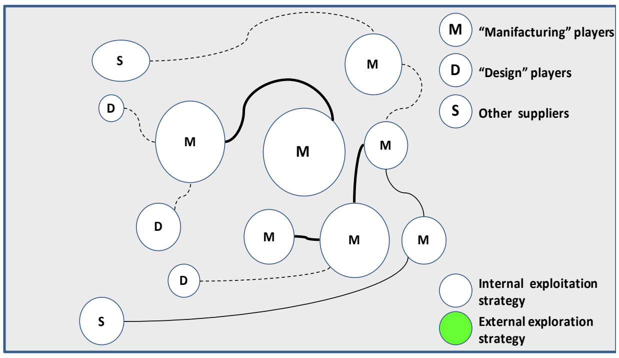

Fig. 5 Scenario 2: Internal Exploitative strategy

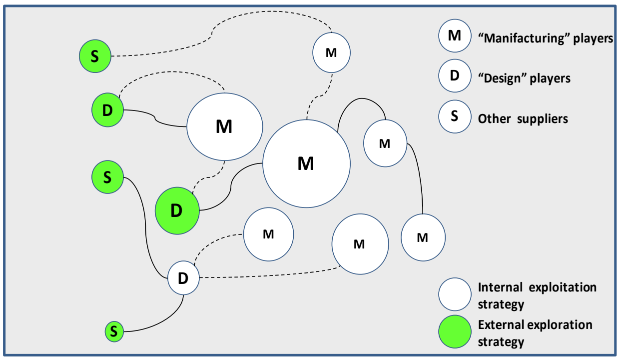

Fig. 6 Scenario 3: Internal Explorative strategy

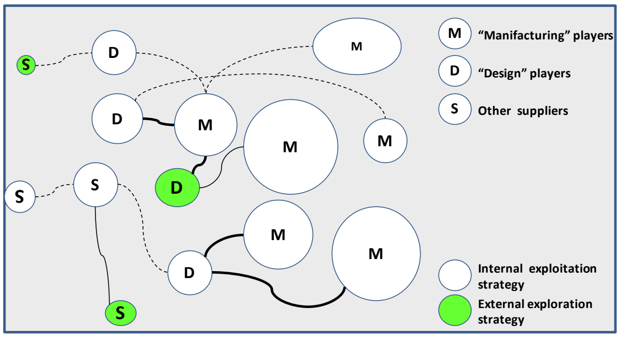

Fig. 7 Scenario 4: External Exploitative strategy

In brief, the results of different scenarios simulations considering change of number and strength of new or old links are displayed in the following table

Managerial attention	Strategic orientation: Exploitation	Strategic orientation: Exploration
Internal	New links: = / Old links: –	New links: + / Old links: =
External	New links: ++ / Old links: +	New links: ++ / Old links: ++

– decrease; = stable; + increase. Upper triangle: New links; lower triangle: Old links.

IV. CONCLUSION AND FUTURE WORK

Thanks to the simulation model we can observe the network evolution and identify the main factors that influence these changes. i designers cope with the environmental uncertainty of 3 D printing technology by increasing alliance activities and have access to new resources, capabilities and skills required for that new technology t. In time, the improvement of new links will bring , as an ancillary effect, an increase in designers' resources, competences and skills and a decrease uncertainty. This process will guide the designer to acquire more power inside the network and attract more partners.

The designer that has an external focus and an exploration strategy is the one who will have a greater increase in the number of alliances, both new and old. In fact, while the external focus helps the organization to perceive the uncertainty created by the radical innovation diffusion, the exploration activities drive the organization to explore new links and actors who may be able to develop their strategy. This process helps designers to decrease their uncertainty on the new technology diffusion and become central actors inside the network. The central role drives the other nodes to join the central organization decreasing the information asymmetry: for this reason the number of the old links increases. On the other hand, designers that have an internal focus exploitation strategy will not perceive the innovation diffusion inside the network because their interest understands internal variables. Moreover, the exploitation activities will limit the creation of new links on behalf of the organization who will prefer to "exploit" persistent links rather than explore new alliance solutions.

This behavior establishes a negative cycle in which the current partners, who perceive that uncertainty has increased because of innovation diffusion, prefer to break off the links with their current designers.

Along with the previous two conditions of extreme behavior on behalf of the designers, there may be two more situations: an external focus with exploitation activities and an internal focus with exploration activities.

In the first case the external focus will help designers to perceive the uncertainty but not the correct strategy to link with new partners. So this strategy could be appropriate if the actors inside the network have already decreased their uncertainty while using 3D printing.

Finally the internal focus with the exploration activity will not affect the designer's old ties, but slightly increase the strategy activity of new links.

As Koka [39, 40] recommended, the perception of uncertainty at high levels of uncertainty is likely to be muted, given that managers are already being subjected to shocks from different sources, reducing the pressure on them to respond. On the other hand, in more predictable environments, any increase in uncertainty is likely to be immediately noticed which raises the likelihood that managers will respond to that shock.

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