Professor Luca IANDOLI, PhD
E- mail: luca.iandoli@unina.it
Cristina PONSIGLIONE, PhD
Email: ponsigli@unina.it
Giuseppe ZOLLO
Email: Giuseppe.zollo@unina.it
Department of Business and Managerial Engineering
University of Naples, Italy

MODELLING NETWORKED COGNITION: A SOCIO-COMPUTATIONAL APPROACH

Abstract. *In this paper an agent-based model is proposed in which effects of collective cognition are represented via the operazionalization of the construct of collective memory. The model is aimed at representing an evolving local networks of suppliers and final firms competing among them, making alliances and selling products on the market in the presence of environmental instability. A set of hypothesis has been tested in order to evaluate the influence on network's performances of collective memory.*
Through the proposed model, this article illustrates advantages and limitations of computer based models to investigate collective cognition. The extent to which computational approaches can be used to model collective cognitive constructs such as collective memory and learning and their influence on social action is examined. Finally, implications for research and practice on organizational cognition resulting from a social computation view are outlined.
Key words: *collective memory, social networks, agent-based simulation.*

JEL Classification: L14, L23, C63

Aim of the article

Collective cognition has been the subject of many studies in research on organizational cognition. Some scholars have underlined the metaphorical nature of collective cognition by recognizing, however, the potential of such metaphor in providing explanations about how people think and act within organizations (Morgan, 1997). Lant and Shapira (2001) classify approaches to organizational cognition within a dichotomy between information processing and sense-making approaches (Daft and Weick, 1984). Moving along this dualism, other research efforts have been directed toward methodological issues concerning how to represent and model collective cognition and information flow in groups and organizations, such as mapping, social network analysis, and qualitative methodologies such as ethnography and discourse analysis.

More recently a multidisciplinary approach to collective cognition known as social computation (Tefstation, 2001) has emerged at the cross point between sociology, cognitive psychology and computer science. According to the social computation perspective, social behavior emerges from interaction among "cognitive" agents within social networks. Such approach assumes heterogeneity, bounded rationality, interdependence of cognitive agents, and absence of any centralized control mechanism. Consequently, aggregate behavior and attributes are not merely metaphor or extension at the collective level of individual constructs, but observable properties arising from distributed ongoing interaction.

A further advantage of social computation is that the development of social simulation models permits to construct a virtual lab: through such computer models, called agent-based models, it is possible to explore the dynamics of social phenomena emerging from the bottom, starting from the micro-specifications describing agents cognitive models and behavior. An agent-based simulation model can provide a computational demonstration that a set of hypothesis, related to agent individual behaviour and cognition (micro-specifications), is sufficient to generate certain social aggregate (Epstein and Axtell, 1996).

In particular, agent-based models can provide explanations for self-organizing behavior of complex systems, which is difficult to describe through other methodological approaches:

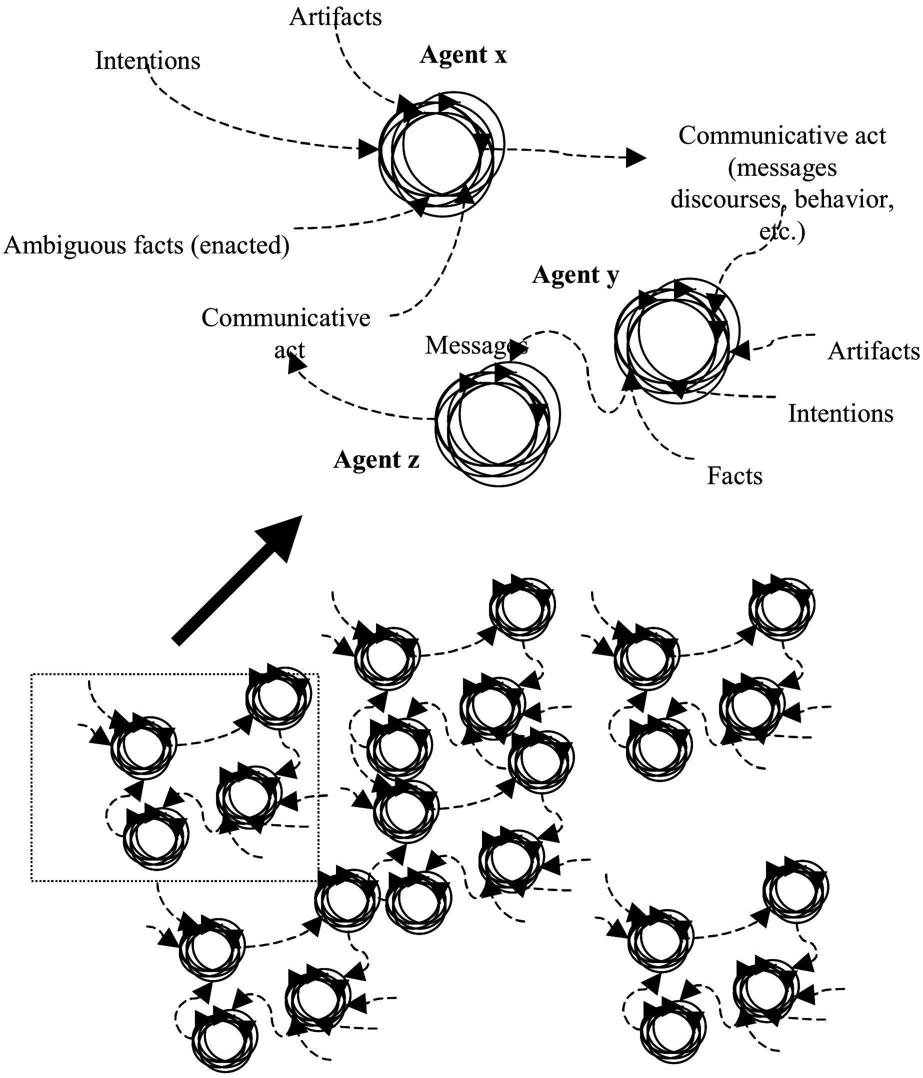
- qualitative methodologies, such as narratives and case studies are based on subjective interpretations and lack the rigor and reproducibility of quantitative analysis;
- quantitative methodologies such as structural equations and statistics become analytically intractable when complexity exceeds certain thresholds; besides they require ex-ante knowledge of the phenomenon to build an explicit model.

This article focuses on social-organizational networks considers as Complex Adaptive Systems characterized by the following properties (Rullani, 2002): interaction between cognitive agents, lack of centralized control, agents adaptation and continuous evolution, presence of unpredictable changes, bounded rationality of agents. In particular we present an agent-based model in order to explore the impact of collective memory on system's performances in the specific case of small firms networks. The results will be analyzed to discuss advantages and limitations of using computer based models to investigate collective cognition and how research and practice on organizational cognition may benefit from a social computation view.

A networked approach to collective cognition

The approach to collective cognition proposed in this article is based on social system theory (Luhmann, 1995). According to this view social systems are autopoietic systems (Maturana e Varela, 1980), i.e. systems able to reproduce themselves through self-reference and self-organization. Organizations can be seen as *contingent social networks* ("nor necessary, neither impossible", Luhmann, 1995) made up by heterogeneous and autonomous agents. Social structures and action are not determined by necessity, but by the joint effort of individual agents to reduce unpredictability and ambiguity arising from unstructured social situations. For example organizational roles can be considered as a set of expectations that people attribute to given individuals within an organization; organizational routines can be seen as standard procedures helping people to standardize their own and others' behaviors (Nelson and Winter, 1982); culture ensures group continuity and integration (Schein, 1985); institutions help collectives to store and consolidate social practices (Berger and Luckmann, 1966).

Figure 1: Organization as contingent social networks made up by cognitive nodes



In contingent social networks agents continuously (re)create sense through loosely-coupled social interactions with other agents and produce communicative acts by elaborating and linking experience, enacted facts, intentions, theories of action, messages produced by other agents. Thus, organizations can be seen as relational contingent network constructed through the connection of cognitive nodes (agents), interpreting ambiguous facts and messages, making choices, and creating meanings. Overall, organizations incessantly reproduce themselves through communication process and sense-making (fig. 1).

According to the contingent perspective, the network is not a metaphor describing a new organizational paradigm but the underlying structure for the production of collective action. As such the network paradigm can also be applied to interpret more traditional organizational structures; hierarchies, procedures, rules, control systems are means through which organizations try to constrain individual sense-making within predefined interpretative schemata often determined by power relationship (Crozier and Friedberg, 1977).

Formalization hides the chaotic nature of the network beyond appearances of order. In other words, order, linearity, hierarchies, predictability are superimposed to the networked nature of organizations as attempts to simplify the complexity and the contingency of the net. Tayloristic organizations try to dismantle the network and to assembly relationships along the allowed dimensions of sense of efficiency and scientific management; bureaucracy forces relational cycles within a space of action strictly constrained by formal rules. However, traditional organizational paradigms are not able to destroy the intrinsic autopoietic nature of social networks: the production of collective action through sense-making within structured, but contingent, systems of relations and the self reproduction in the realm of sense.

In sense-making systems the role of language, discourses, and more in general, of communication is not limited to the sharing and transferring of information, but to meaning re-elaboration and construction. Each communicative act, being produced in the realm of sense, incorporates an irreducible amount of ambiguity. As such, each communicative act may trigger multiple, even conflicting, interpretations. Cognitive agents spends most of their time to re-elaborate and produce messages, but each production of sense, carried out in the attempt to reduce ambiguity, produce other meaning. Sense produce sense (Luhman, 1995), communication generates communication; eventually, collective action reproduces itself through communication.

Definitely, meaning proliferation, whilst representing a source for innovation and creativity, represents a threat to stability and predictability. For this reason, organizations, which can not give up meaning production, build continuously ways to stabilize meaning.

Search for consensus is the result of the tension toward stability and it is needed in order to prevent collective action from stopping because of proliferation of communicative acts, interpretations, and interpretations of interpretations.

Stability is the product of a collective will aimed at ensuring the persistence and the regularity of collective action. Nothing necessary or deterministic characterizes persistence, nor reciprocity of social action has to be taken for granted thanks to the sharing of institutional or super-individual objectives.

If organizations appear as stable and characterized by a recognizable order this is due to two main reasons: on one hand they reproduce themselves by nurturing those cycles aimed at enforcing persistence, regularity and predictability of collective action; on the other hand, the sense-making cycle contributes to produce social compromise and more or less tacit consensus behind the dominant, visible values, power and relational system.

How to limit the proliferation of meaning? How to make meaning and organizations stable and durable? How to reduce ambiguity and anxiety produced by contingency?

A possible answer is through the construction and the maintenance of a collective memory, meant as integration of shared rules, admissible behaviors and organizational culture, providing individuals with a stable set of meanings, interpretative schemata, cognitive frames supporting action and inter-action within the network. In the next section we explore the concept of collective memory and its role of coordination mechanism within social networks.

Collective memory as coordination mechanism for social action

Memory and meaning stabilization

The role of collective memory in the stabilization of social meanings has been investigated in depth in socio-constructionism. According to Berger and Luckmann (1966), institutions are the product of the accumulation of collective knowledge. The main characteristic of any durable social aggregation lies in the progressive construction of consuetudinary social practices: the repetition of individual actions allows members of a group to describe and recognize typical actions through established schemata applied by individuals to anticipate other members' behavior.

Repeated practices allow group members to achieve, through individual contributions, super-individual objectives, such as the survival of the group and its continuity. When individual action is repeated through shared schemata, a process called "routinization" takes place. In the long term, routinization generates reciprocal expectations among group members concerning individual behaviors and makes social action impersonal and anonymous since it is no longer attributed to particular individuals but to social Roles and Institutions.

In other words, 1) habits provide a basis for the division of social tasks among group members, 2) tasks are attributed to specific individuals and are executed according to shared patterns of action; 3) in the long run, repetitions and routines become anonymous, impersonal and objective and are not more associated to specific individuals but rather to social roles having certain recognizable attributes and characteristics, 4) this impersonal but shared knowledge, which is built through social action, ultimately influences individual behavior.

Routinization and anonymity are not sufficient to create an institution if other two characteristics are lacking: first, institution must have a "history", second, institution must provide individuals with behavioral guidelines to which they are requested to adapt. Consequently:

a) institutions are the result of a process of collective accumulation of knowledge that is created through repeated interaction;
b) collective knowledge influences individual behaviors since it provides individuals with behavioral guidelines and shared values.

The institutional approach (Scott, 1995) conceptualizes such body of shared knowledge as a collective memory and posits that shared memory does play a role in shaping relationships between agents within social networks. If individual behaviors are influenced by past knowledge accumulated both into a collective and subjective memory, then modeling social networks by only considering current agent-to-agent and agent-to-environment interactions and information exchange may be reductive and unrealistic. For example, due to the presence of a strong collective memory, a group may experience inadequate capability to react to sudden changes that could be hardly explained by other models in which only current interaction and information flow are considered. But, if collective memory has to be considered as a relevant social coordination mechanism, it is necessary to identify possible ways through which such a concept can be described and modeled.

Toward an operationalization of collective memory

Any attempt to describe and model concept of collective memory raises a number of questions: which elements constitute collective memory? How and to which extent social and individual actions are influenced by collective memory? IN this section we provide an operazionalization of the concept drawing from the above considerations and existing literature on knowledge-based theory of the firm, organizational cognition and inter-organizational networks

Knowledge accumulation through time by individuals within more or less structured collectivity has been largely investigated in organizational literature, as partly already outlined in the previous sections.

According to the knowledge-based approach to the theory of the firm companies are “repositories of knowledge” (Penrose, 1959), systems integrating specialized knowledge able to preserve and generate knowledge (Grant, 1996), systems able to learn through trial and errors process (Herriot, Levintal and March, 1975) and that build and select routines (Nelson e Winter, 1982). Schein (1985) argues that the accumulation of social practices produces the creation of a collective culture, i.e. a set of basic assumptions shared, invented or developed by a group in the attempt to resolve a trade off between external adaptation and internal integration, that have proven to be successful and that must be taught to new members of the group as the right way to perceive, think, behave in certain specific circumstances.

Though all such studies emphasize the role of past knowledge and of knowledge exchange and creation within collectives and provide useful elements to characterize how collective cognition takes place, they do not make an explicit reference to collective memory, nor they propose an operative definition of such concept.

A notable exception is represented by the work by Walsh e Ungson (1991), in which a model of organizational memory is proposed. In particular, they assume that organizational memory has a distributed structure made up by the connection of both tangible and intangible "retention facilities" in which knowledge and information are stored within organizations: organizational structure, transformations (i.e. production routines), ecology (i.e., work physical environment), organizational culture, external archives.

The model proposed by Walsh and Ungson and other works on organizational memory has been conceived with respect to structured social networks such as organizations; consequently, it lacks generality if adapted to more loosely coupled forms of social networks, such as firms' networks and informal groups. Furthermore, in their effort to make tangible and analyzable the collective memory, Walsh and Ungson do not investigate the socially constructed nature of collective memory and the dynamics through which it is constructed, modified and evoked by social actors.

Research on inter-organizational networks has also investigated the role of past knowledge in influencing networks performance and individual behavior. Soda *et al.* (2004) outline the effects on outcomes of enduring patterns of relationships and that "a past network with its accumulated relational experience becomes a kind of «network memory» that cannot be ignored as it may project a structural overhang over the present, much like a shadow of the past" (p. 893). Uzzi (1996) relates firms' networks performance to embeddedness, that is the capability of a social network to develop dense and strongly interconnected relationships among firms based on mutual trust, reputation, resources sharing and complementarity (Dyer and Singh, 1998).

On the bases of the above considerations, we propose the following definition of collective memory in social networks: *the set of shared social practices and values supporting the self-reproduction of social behavior through long term learning processes based on repeated interaction, meaning stabilization and on the sharing of a common patrimony of resources, routines, competencies, values and objectives.* The operational construct of the collective memory is made up by the following elements:

a) values: values represent shared beliefs about what is considered good and desirable both from an ethical and practical point of view;
b) routines can be thought of as standard procedures, scripts, recipes through which agents make things happen;
c) resources, representing inputs for action and survival;
d) competencies, representing knowledge skills and know-how;
e) objectives, here meant in the strategic sense as the results to be achieved together with "right way" to compete, learned and transmitted as shared knowledge.

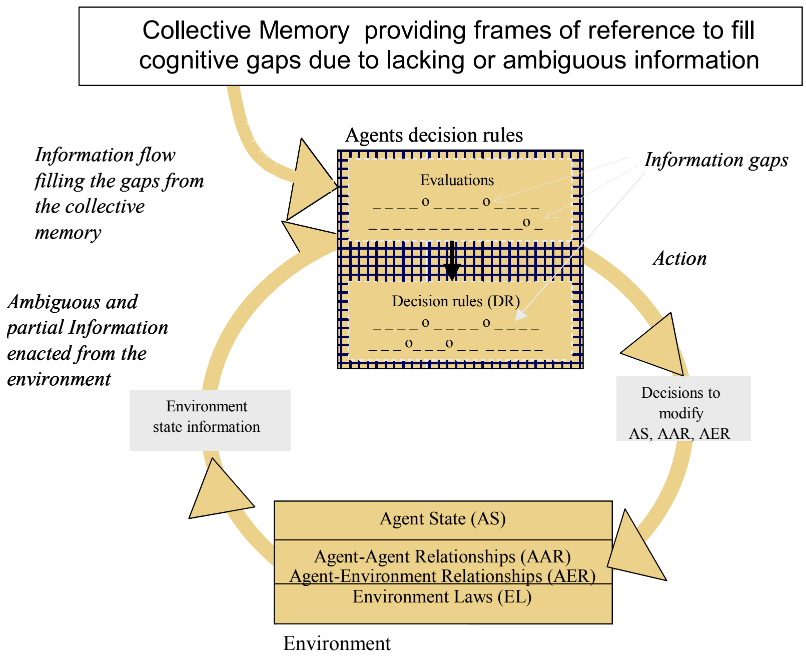
Collective memory as coordination mechanism for social action in firms networks

In this section we try to better clarify the role of collective memory as coordination mechanism for social action in the specific case of social networks made up by final and suppliers firms into geographical clusters. We present a theoretical framework that has informed the development of an agent-based model as illustrated in the following section. The model depicted in fig. 2 is made up by the following conceptual blocks: collective memory, agents models, environment structure and information flow.

Collective memory

In the proposed example, agents can be suppliers or final firms in firms local network. Firms are provided with bounded rationality. In order to cope with such a limitation, agents evoke collective knowledge stored in the collective memory. Collective memory provides agents with default knowledge useful to cope with recurring and stereotypical situations. In other words, the presence of a consolidated knowledge patrimony refined through experience and reinforced by consensus helps firms to overcome lack of information by recurring to tradition and routines. If on one hand, collective memory may imply a sort of cognitive economy for firms since it helps to make sense-making less problematic, on the other hand, in presence of novel and unpredictable competitive scenarios it may turn into a cognitive rigidity and incapability to innovate and react to sudden environmental changes.

Figure 2. The role of collective memory in the coordination of social action



Agents models

Agents (firms) are described by a set of competencies, state variables, evaluation and decision rules. Competencies represent firm skills, knowledge and capabilities, while state variables represent their internal resources and values. During the simulation, firms may decide to improve their competencies by comparing their current levels of competencies with target ones required by the market. Firms have a bounded rationality and the acquisition and processing of information is costly. For this reason, firms face investment trade-offs, regarding to the selection of the competencies to be improved.

Environment structure

This conceptual block entails some elements pertaining to the competitive environment. One is the inter-firms scaffolding structures needed to co-ordinate production processes. In our model, final and subcontracting firms are not able to sell their products alone. Nevertheless, they can interact to exchange information, materials and products. Through this exchange, they are able to sell their products on the market. Thus, the interaction context of the model is represented by formation of supply chains into local networks of small companies; the latter will be indicated as "production chains".

In our model target competencies are determined by the market. At some point in the simulation, product quality may increase, driving firms to improve their competencies in order to meet new quality standards. Different market segments can be progressively introduced in order to model market turbulence. In fact, one of the purposes of this work is to analyze how collective memory influences firms capability to face market turbulence and how long it takes them to reach new competencies levels.

Information flow

The proposed model assumes that final firms have higher strategic capabilities than subcontracting ones; this is translated in final firms capabilities in converting market inputs (competences target levels) into internal information. The information and production flows are structured as follows:

- final firms receive external information about products requirements from the market in terms of competencies target levels;
- subcontracting firms receive product requirements interacting with final firm;
- once created, production chains sell products to the market and receive a profit, which is a function of product quality.

The agent-based model

In order to represent a social network through an agent model we need to characterize three basic elements:

- Agents: individuals of the virtual social network, each having internal states and behavioral rules that may be modified through interaction with other agents or with the environment;
- Environment: a network of renewable resources and environmental constraints;
- Rules of behavior governing agent/agent and agent/environment interactions.

Simulation models can be implements through available software tools, such as the open source platform SWARM or less flexible but simpler to use software shells like AgentsSheets® or Agent Builder® providing graphical facilities and requiring low or none computer programming skill.

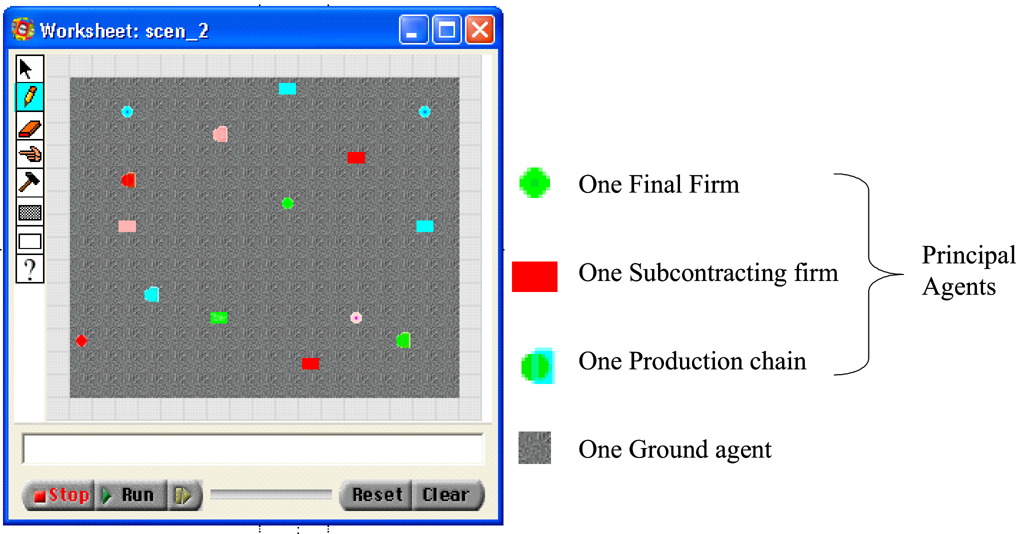
Applications of agent-based models to social simulation have usually focused solely on current interactions without explicitly recognizing the role of collective socio-cognitive constructs such as shared knowledge, institutions and collective memory.

The theoretical meta-model depicted in fig. 2 has been translated into specifications for the design of agents' rules of behavior, communication and interaction mechanisms in a network of final and supplier firms. The computational model has been implemented by AgentSheets® platform.

The environment

Agents are placed together into a virtual environment in which they interact by checking conditions, based on information about themselves or on information obtained from agents in other cells, and executing those actions whose conditions are met (fig. 3).

Figure 3. The simulation work space – AgentSheets worksheet



In the model the work space – worksheet – is defined by ground agents.
District firms stand and move on ground agents.

To represent in computational terms the environment structure three market segments: S_1, S_2, S_3 have been defined. Given levels of competencies allow firms to have access to given market segments: $S_i = (M_i, T_i, P_i)$, where M, T and P represent the target level for, respectively, market, technological and relational competencies to be competitive on the segment. Segments are ordered in term of how much is easy to access them with S_i being easier than S_j if $i < j$. Information relative to target levels required by market segments is spread through the environment so that firms can perceive the existence of different market segments and can select which one to pursue.

Firms that decide to move from S_1, to S_3 have to increase their competency levels; on the other hand, they are motivated to move to higher segments to get higher profitability. For example, the three segments market might stand for: local market, national market and international market.

Agents

According to flexible specialization theories (Piore and Sabel, 1984), we modeled the firms network as a system of small and medium firms that interact to realize a product. We define three classes of agents: final firms, subcontracting firms and production chains.

The principal objective of final firms is to meet market requirements; they try to achieve this objective by building up production chains. Production chain efficiency is measured in terms of achieved quality during the production phase and production costs. Subcontracting firms are firms providing raw materials, components and semi-finished products to final firms. Their objective is to search for an adequate final firm in order to buildup a production chain. The interaction structure between final and subcontracting firms is based on production chains, formed, for the sake of simplicity, by only one final and one subcontracting firm. When a final and a subcontracting firm join together to generate a production chain they disappear from the model and they form a new agent, however without loosing memory of their individual characteristics. Firms belonging to the same chain exchange information and products, in order to accomplish the production process and to sell the product/service to the market. The objective of production chains is to sell their products to the market, and to seek for more and more profitable markets.

Each firm is characterized by state variables, competencies levels and economic resources. This state can progressively changes in each iteration (cycle) of the simulation, accordingly to firm choices and interactions with other agents of the model. Thus, for the cycle *i-th*, firm's internal state (IS(f_i)) is function of: IS(S_i)= f (m_i, t_i , p_i , opp_i , $risk_i$, bdg_i) where:

- m_i represents the level of market competencies: production chains with higher levels of m_i have more probabilities to sell their product to the market;
- t_i represents the level of technical competencies, strictly related to product quality and to the specific production routines;
- p_i represents the level of relational competencies, like partner selection, alliances creation, organizational competencies within production phases, information exchange;
- opp_i is the degree of opportunism;
- $risk_i$ is the risk propensity;
- bdg_i the budget function, i.e. the amount of economic resources of the firm

A fundamental element of the collective memory is given by values representing shared beliefs about what is considered good and desirable both from an ethical and practical point of view. For the sake of simplicity, in our model, we consider only two values: opportunism and risk propensity. Firms' attitudes towards these two behavioral dimensions are recognized as main determinants of economic behavior (Williamson, 1975). However, the structure of the model is such that it is relatively easy to include other values by keeping into account the specificity of the collective memory of a given network.

Opportunism is represented through a binomial variable, assuming values "0" (low opportunism), and "1" (high opportunism). Final and subcontracting firms with high opportunism will search for partners with competencies levels greater or equal than their own. Furthermore, opportunistic firms are more willing than non opportunistic ones to break up an existing chain if they meet a better partner. Low opportunistic firms form chains without considering competencies levels as prejudicial and are more loyal.

Risk propensity variable indicates agent's inclination to carry out investments. Firms with high values of this variable will set competencies improvements as primary objectives. Risk is a binomial variable, where "1" stands for high.

Competencies variables (m_i, t_i, p_i) are measured on a discrete point scale ranging between 1 and 9, where 1 indicates the lowest value. Competencies are part of the collective memory of the network, so their levels and their descriptions have to be represented by keeping into account the characteristics of the specific network being modeled.

When simulation starts we assume that the network is populated only by final and subcontracting firms having certain initial values of competencies levels. Instead, for production chains the initial values are determined when the chain is built up.

Simulation Steps

In AgentSheets applications, agents' actions (searching, looking, sending messages, etc.) are defined by set of *if-then rules*. The typical behavior of an agent is made up by the following steps (fig. 4):

Step 1 - Internal state check: At the beginning of each cycle, firms check their internal state: $IS(f_i) = f(m_i, t_i, p_i, opp_i, risk_i, bdg_i)$. To limit complexity we assume that some of the state variables (opp_i, $risk_i$) do not change their values during simulation. This is also to keep into account the inertia of collective memory. Instead, economic resources and competencies levels vary and result from previous cycles. In particular, if the amount of economic resources of a firm agent is less or equal to zero the agent dies and disappears from the simulation worksheet.

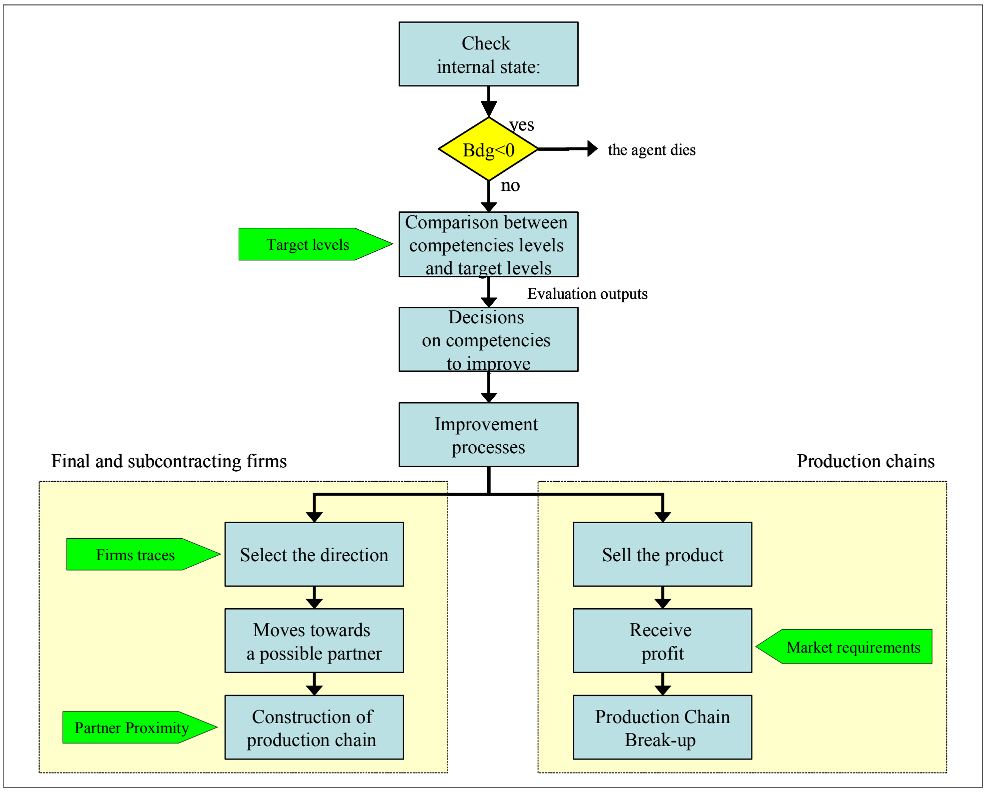
Step 2 – Evaluations: Firms evaluate their levels of competencies by comparing them to the target levels given by the market.

Step 3 - Improvement strategies: In this step, firms choose their improvement strategies, according to their internal state and objectives and establish the direction for environment exploration (step 4). Firms have to decide which competencies to improve. Being constrained by their scarce economic resources firms face investment trade-offs and estimate the different profits they might obtain with different competencies profiles. We make the simplistic assumption that when firms invest its resources for competencies improvements they always get a return in terns of higher competencies level.

Step 4 - Environment Exploration: Firms move into the environment to achieve their objectives (look for partners, look for information, etc.). Agents are required to invest money to move in the search space. Such investment represents the costs they have to bear for information search.

Step 5 - Production chains generation or break up: The objective for final and subcontracting firms is to become part of a production chain by finding and selecting a partner. Opportunistic final firms will select only subcontracting firms with competency levels greater or equal than their own. Subcontracting firms are not able to select for final firm. However, they move closer to attractive (in terms of competencies levels) final firms in order to be selected by them. Final and subcontracting firms with low opportunism tend to not break an existing chain when encountering potential partners having competencies levels higher than the actual partner.

Figure 4. Flow chart of agents behavior during the simulation



Step 6 - Product sale: Every production chain assembles and sells its product to the market and receives a profit after that products are sold. Product sale happens randomly but higher quality product have more chances to be sold. Profit is a function of market segment profitability and of product quality; the latter is a function of the competencies gap of the firm. Moreover, final and subcontracting firms cannot sell any products on the market, thus if they do not form a production chain they will sooner or later die during the simulation.

Hypothesis

The architecture of the agent model was developed in order to represent the complexity connected to evolutionary dynamics and learning processes in social networks, with focus on firms networks. Many elements that define agents' state, communication mechanisms, information flow and environment structure are derived from collective memory. The simulation aim is to observe how and to which extent collective memory may affect firms networks performances and overall behavior. More in detail, the hypotheses that we are going to verify through a set of generative experiments can be synthesized as follow:

- H1: collective memory has a moderating effect between firm's network performances and environmental changes; i.e. performances in turbulent rather than in stable scenario depend on the contents of collective memory;
- H2: when collective memory is strongly shared among agents, i.e. when most of the firms show rather homogeneous values in terms of competencies, values, objectives, routines and resources, the network risks high closure and experiences relative inability to adapt to environment changes.
- H3: when collective memory keeps a certain level of diversity among agents, the system increases its performances in presence of turbulent environmental conditions.

Experimental Sets

Each generative experiment starts with 40 agents: 20 final and 20 subcontractors firms and lasts for 180 cycles. At the beginning of the simulation there are no production chains, but they will appear later originated by the interactions between final and subcontracting firms. In the experiment simulation focuses only one component of the collective memory, i.e. values. At the beginning of each experiment, the same level of competencies and of economic resources characterizes final and subcontracting firms, but they show different values of risk propensity (risk) and opportunism degree (opp). *Opp* and *Risk* variables are binary: 0 indicates low (L) and 1 means high (H). Thus, each agent can be positioned in one of the four quadrants of the following matrix (Table 1)

Table 1 Agents values

Risk	**H / L**	**H / H**
0.5	**L/L**	**L/H**
	0.5	*Opp*

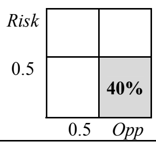
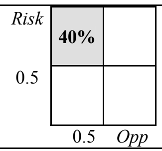
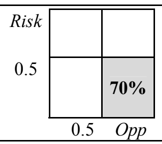
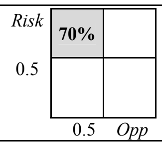
Different starting populations can be defined by changing agents' distribution in the four quadrants of the above matrix. The higher is the presence of agents in one of the four quadrants, the higher will be the degree of homogeneity of the collective memory, other things being equal.

The starting distribution of the populations is called *closed* when at least the 70% of agents belong to only one out of the four quadrants of table 1; in these cases the diversity of the population is low. The a starting population is defined as *intermediate* when there is a slight prevalence of one type of agent (40%) in one quadrant, and remaining ones are randomly classified.

In this way, several *intermediate* and *closed* starting distributions can be set, as showed in Table 2 where six possible cases are depicted. Experiments have been done considering stable and turbulent market scenario, where stable (turbulent) market means slow (fast) changes in market requirements; in fact, the two market scenarios are modeled in terms of temporal distance (number of cycles) that elapses between two changes of market conditions. In the stable case this distance is constant during simulation (20 cycle), while in turbulent case it is variable and shorter.

Twelve experimental sets (6 agents distributions x 2 scenarios) have been considered in order to observe how firms' network performances change in different settings. To measure the performances of the network we introduced two variables: P**,** representing the overall economic performance of the network, computed as the sum of the budgets of all the firms (final, subcontracting and production chains) at each simulation cycle, and N**,** number of survived firms at the end of each simulation cycle.

Table 2 Initial populations (the percentages indicates the portion of agents that take value in each quadrant)

Starting Population Distributions	
I. Intermediate	II. Intermediate
	
III. Closed	IV. Closed
	

Results

We performed fifty runs in each experimental set. Thus, for each simulation 50 pairs of values for P and N have been obtained. The 50 pairs were ordered according to increasing P and plotted on a two-dimensional graph (fig. 5). Then for each experimental set statistics for P and N have been calculated (tab. 3).

Table 3 Average values for N and P on the 50 runs for set I-IV

Environment	Stable Case		Turbulent Case	
Experimental Set	N	P	N	P
I – Intermediate	11.96	79.25	7.40	31.03
II – Intermediate	11.66	79.78	8.20	40.42
III – Closed	11.34	66.86	6.42	19.10
IV– Closed	10.94	88.57	6.98	33.63

The first and the third experimental sets are characterized by high opportunism and low risk, the only difference being in the degree of homogeneity of values (70% in closed vs. 40% in intermediate). These last two sets are indicated as "Low cooperative Network (LCN)". On the contrary, the second and the fourth sets, characterized by high levels of risk and low opportunism are indicated as "High Cooperative network (HCN)". Through the analysis of table 4 we compared the performances of these two types of networks in terns of profit (P) and survival (N) in different competitive scenarios.

Analyzing the table above moving from closed to intermediate, it is possible to make the following assertions:

- Low cooperative Network: higher diversity rewards more in the turbulent case. This also means that decreasing opportunism helps the overall network to perform better;
- High cooperative Networks: higher diversity rewards only in the turbulent case. This means that strong cooperation in HCN is desirable only in stable conditions. This also implies that cooperation should not be considered a value per se.
- the highest performance increment is computed for LCN in the turbulent case. This means that increasing cooperation where there is none or little is relatively better in terms of performance gains than increasing opportunism where there is none or little.
- In turbulent cases an increase in diversity is always rewarded with an increase in performances. In stable cases increasing diversity implies only a slight improvement for LCN and a slight decrease in performance for HCN.

The simulations within various experimental sets have been used to verify the hypotheses of this research work. The first hypothesis of this work (Collective memory has a moderating effect between network performances and environmental changes) is confirmed by the simulation experiments carried out. Considering the two competitive scenarios introduced (stable or turbulent) we proved that memory has a moderating effect between performances and environmental changes. Of course, one has to keep into account that this result has been obtained by considering only a limited number and only certain kind of values.

In addition, the second and third hypothesis have been partially confirmed by the simulation experiments. Comparing the results of intermediate and closed populations, we verify that the intermediate populations have, in general, higher performances then closed ones (the N and P values), but, in stable cases, this difference is not substantial; on the contrary, in stable cases the diversity for HCN produces worse economic performances (P values).

Table 4 Comparison between HCN and LCN results

Environment \ Population		Intermediate N	Intermediate P		Closed N	Closed P
Stable	***LCN***	11.96	79.25	***LCN***	11.34	66.86
	HCN	11.66	79.78	***HCN***	10.94	88.57
Turbulent	***LCN***	7.40	31.03	***LCN***	6.42	19.10
	HCN	8.20	40.42	***HCN***	6.98	33.63

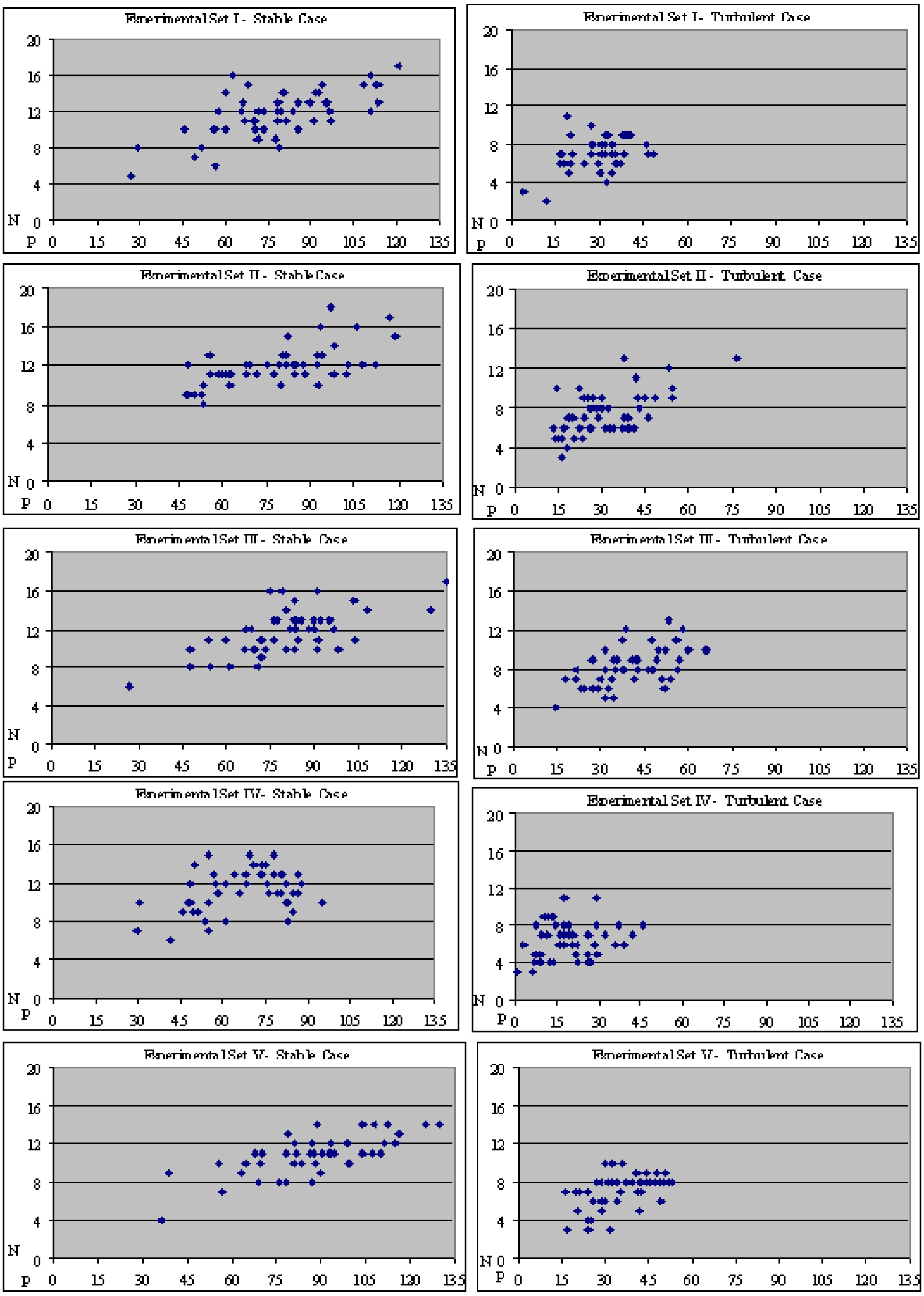


Figure 5. Results of the fifty runs performed for each experimental set.

Conclusions

The results show that network performances are influenced by collective memory. Namely, we have showed how variations of opportunism degree and risk propensity may cause different impacts on network performances according to different degree of environmental stability. Some results were unexpected.

Strong cooperation appears to be not always desirable, as HCN experience inability to change in turbulent environment. This is actually what Italian Industrial districts are experiencing in facing increasing turbulence due to global competition. This effect also was confirmed by other empirical research. Uzzi (1996) demonstrates how the relationship between firms survival and embeddedness is U-shaped. Similarly, diversity is not always rewarding (HCN in stable scenario).

Regarding research implication for the study of distributed cognition, the socio-computational approaches can bring some relevant insight and research perspective for organizations and more in general the management of less structured social aggregates as communities of practices or Knowlegde ecosystems made up by both human and artificial agents (Scarlat and Maracine, 2008).

First, by recognizing that social action and social systems have a contingent nature, social simulation techniques possess many features that make them suitable to model social networks and collective cognition: lack of determinism, absence of centralized control, presence of autonomous bounded rational agents, emergence of complex phenomena from simple behaviors. The complexity of a social system actually originates from the multiplicity of possible states that sense-making systems can assume in consequence to even slight changes of a few critical conditions. Such complexity, which can not be observed and analyzed through traditional quantitative techniques, can be better managed through computational models and simulation.

Second, agent-based models help to consider the effect on social networks and individual behavior of collective constructs obtained by merging a cognitive and an institutional perspective: in our model collective memory has been operationalized and its influence of network performances has been observed. In other words, one may argue that the computational approach helps to instantiate and represent collective cognition in a more operational way than metaphors.

The proposed approach and the model presented in this paper have several limitations, including: top-down role of collective memory, constructs operazionalization, presence of some simplistic assumptions adopted to keep the model simple enough. Though the proposed agent-based model could be made more realistic by including other elements and variables there is a price to pay in terms of robustness. This is a major trade-off in the design of agent-based models. For example one may create more sophisticated agents' behavior, add other meaningful variables to values, increase the variety of typology of agents, resources, competencies, introducing new environmental characteristics, but the increase in the number of parameters will make results less stable and harder to interpret.

Reductionism and simplification make hard to directly employ agent-based models to real world applications. However, there seems to be an interesting potential in using agent-based models to perform what-if analysis to observe effects of policies choices.

Through simulation we have shown that the way a network "reacts" to changes is potentially influenced by current dominant values, routines, strategies and competencies the network has been developing trough time. Such cognitive patrimony can show relevant inertia to changes. Policy makers and managers should then consider the peculiarities of the collective memory and its inertia in figuring out possible interventions aimed at influencing network behavior (e.g. increasing network competitiveness). Thus, through agent-based platforms it is possible to observe unexpected – emergent – phenomena resulting from the introduction of a new policy. Policy makers can define adequate leverages to reach the policy's target. Leverages can be modeled and introduced in the virtual experiment. Then, new simulations can be made and the experiment's results can be compared with the expected results. For example, one could test effect of the constitution of shared research facilities in a firms network, or the result of the adoption of given incentives within a team or an organization.

Acknowledgement

This paper reports some of the research results obtained within the research grant PNII - IDEI 810/2008 - ''The Development of Theoretical Fundaments of Knowledge Ecosystems and Their Applications on Economy and Healthcare", funded by CNCSIS -UEFISCSU.

REFERENCES

[1]**Berger P.L., Luckmann T. (1966),** ***The Social Construction of Reality: A Treatise in the Sociology of Knowledge***; New York, Doubleday;
[2]**Crozier, M., Fiedberg, E. (1977),** ***L'acteur et le système*** ; Paris: Editions du Seuil ;
[3]**Daft, R.L., Weick, K. (1984),** ***Toward a Model of Organization as Interpretation Systems*** *; Academy of Management Review*, 9(2), 284 – 295 ;
[4]**Dyer, J.H., Singh, H. (1998),** ***The Relational View: Cooperative Strategy and Sources of Interorganizational Competitive Advantage***; *Academy of Management Review*, 23(4), 660-679;
[5]**Epstein, J.M., Axtell, R. (1996),** ***Growing Artificial Societies: Social Science from the Bottom up***; Cambridge (MA), MIT Press;
[6]**Grant, R.M. (1996),** ***Toward a Knowledge-Based Theory of the Firm*;** *Strategic Management Journal*, 17, 109-122;
[7]**Herriot, S.R., Levinthal, D, March, J.G. (1975),** ***Learning from Experience in Organizations***; *American Economic Review,* 75, 298-302;
[8]**Lant, K.T., Shapira, Z. (eds., 2001),** ***Organizational Cognition: Computation and Interpretation***; Mawah (NJ): Lawrence Erlbaum Associate;

[9]**Luhmann, N. (1995),** ***Social Systems***; Stanford: Stanford University Press;
[10]**Maturana, H., Varela, F. (1980),** ***Autopoiesis and Cognition*****:** ***the Realization of Living;*** London: Reidl;
[11]**Morgan, G (1997),** ***Images of Organizations***; Thousands Oaks (CA): Sage;
[12]**Nelson R.R., Winter S.G. (1982),** ***An Evolutionary Theory of Economic Change***; Cambridge (MA), The Belknap Press of Harvard University Press;
[13]**Penrose E.T. (1959),** ***The Theory of the Growth of the Firm***; Oxford, Basil Blackwell;
[14]**Piore M.J., Sabel C.F. (1984),** ***The Second Industrial Divide: Possibilities for Prosperity*****;** New York, Basic Books;
[15]**Rullani E. (2002),** ***Il distretto industriale come sistema adattivo complesso***, in Quadrio Curzio, A. Fortis M. (a cura di), *Complessità e Distretti Industriali*, Bologna, Il Mulino;
[16]**Scarlat E., Maracine V. (2008),** ***Agent-based Modelling of Forgetting and Depreciating Knowledge in a Healthcare Knowledge Ecosystem***; *Economic Computation and Economic Cybernetics Studies and Research*, No. 3-4, ASE Publishing House, Bucharest.
[17]**Schein E. (1985),** ***Organizational Culture and Leadership***, San Francisco, Jossey Bass;
[18]**Scott W.R. (1995),** ***Institutions and Organizations, Foundations for Organizational Science***; Thousand Oaks (CA), Sage Publications;
[19]**Soda, G., Usai, A., Zaheer, A. (2004),** ***Network Memory: the Influence of Past and Current Networks on Performance****; Academy of Management Journal*, 47(6), 893-906;
[20]**Uzzi B. (1996),** ***The Sources and Consequences of Embeddedness for the Economic Performance of Organizations***; *American Sociological Review,* 61, pp: 674-698;
[21]**Walsh J.P., Ungson G.R. (1991),** ***Organizational Memory*** ;*Academy of Management Review*, 16(1), 57-91;
[22]**Williamson, O.E. (1975),** ***Markets and Hierarchies: Analysis and Antitrust Implications*** .New York, The Free Press.