Innovation, Networks and Proximity: an Applied Evolutionary Model

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Abstract

This paper investigates the importance of proximity (both *relational* and *geographical*) for partnership formation in innovation systems, in which there is an assumed tacit aspect to knowledge flows. Once presented our rationale for an *agent-based modelling* approach to understand these phenomena, we describe the model where we define two types of agents: firms and institutions. The former aim at innovating and therefore are involved in a continuous learning process which occur both individually and interactively. The latter, on the other hand, play a supportive role, facilitating knowledge flows among firms which possess complementary skills.

Keywords: Agent-based, modelling, innovation networks

1. Introduction

The degree of competitiveness of modern economies has been growing very rapidly in the last few decades. This is largely due to the ongoing process of globalisation which brings into the same market firms located in distant parts of the globe. It is no mystery that the European production system has been threatened by the growing price competition coming from the Far East.

Firms located in Less Developed Countries (LDCs) can relay on a much lower labour cost and, therefore, can produce manufactured products at competing prices. In light of these facts, several analysts and researchers have pointed out how the only viable way out for Northern firms from this *cul de sac* is to empower their innovative capabilities through investments in knowledge creation and diffusion. Such *knowledge-based approach* is grounded on the idea that the ability to create and transfer knowledge is a crucial component in sustaining competitive advantage through innovation and other value generating activities (Pinch et al., 2003; Forsman and Solitander, 2003). In other words, firms' long-term competitiveness crucially depends on their ability to innovate and learn continuously (Florida, 1995; Cooke, 2001; Malmberge and Maskell, 2002).

In this paper we aim at developing a theoretical model able to capture some of the main features that govern learning and innovation dynamics. We will pursue our target developing an agent-based model of interactive learning on social networks. The model will be subsequently calibrated using primary data collected in a backward area located in the south of Italy (the province of Foggia) on a group of firms involved in the production of organic food and a group of supporting local institutions.

The food sector has always been regarded as a low technology industry, having been associated with low-tech transformation of agricultural products. In comparison with other major industrial sectors, research and development activities in the food industry are of minor weight. All the same, the dramatic changes the food industry has gone through during the past few decades did bring about a change of winds. First, the food industry, as most of the manufacturing sector, experiences increased competition both on the domestic and on the international markets. Second, it has been losing the confidence of the general public due to a series of severe food safety shocks like the 'mad cow' (BSE) or Foot and Mouth diseases in the UK or the dioxin in chicken crisis in Belgium. Finally, environmental and cultural concerns have entered the food debate, directing consumers' attention towards issues of long term ecological sustainability as well as animal rights (Boudouropoulos and Arvanitoyannis 2000).

In response to these changes, the food industry found itself in a situation where it was forced to introduce innovations as a response to rising pressures from two fronts. On the one hand, food enterprises needed to keep up with stricter regulation covering food safety, food quality and environmental standards. On the other hand, pressure also arrived from various stakeholders (e.g. environmental NGOs or the general public) to go beyond these statutory regulations. As a result, food standards and labels (such as *organic food*) were developed in order to identify companies that have implemented a strategy that goes in this direction.

In this sense, the fundamental challenge the agricultural sector and food supply chain have been facing over the last few years (and indeed are still facing) is to move from a supply-oriented strategy to a demand-led one, driven not only by economic considerations, but also by social, cultural, ecological and other values which reflect changing consumer preferences and new legal and regulatory frameworks.

Avermaete and Viaeneon identified three ‘innovative’ strategies which are often adopted as a response to the transformation the food industry goes through: (1) food safety and quality systems, (2) environmental management strategies and (3) labelling. “In contrast with conventional innovation, these strategies are based on innovations for which the procedures are set by an external party. At the same time, the strategies go far beyond technological innovations. Information, communication and networking play a key role for successful implementation of the three mentioned strategies” (Avermaete and Viaeneon, 2001: 3).

Our applied study goes along these lines. Using the Foggia organic food database will allow us to investigate the potential innovative capability of this cluster of firms. Moreover, it will allow us to model the actual role played by formal institutions in facilitating information, communication and networking.

So far, the Foggia cluster of organic food producers has proved to be not very efficient in transferring knowledge among involved agents (see Morone, Sisto and Taylor, 2004). However, its network’s architecture showed potential for knowledge transfers. Implementing a calibrated theoretical model of innovation fostered by individual and interactive learning will allow us to investigate the true potential of this network of firms and, eventually, prescribe some policy measures to enhance knowledge diffusion in such a network.

The paper is structured as follows: in section two the literature on informal learning and firms’ innovation is briefly reviewed. In section three we describe the case study and present the data used for the model calibration. Section four describes the model features and in section five we present the results of several simulation runs. Section six concludes the work and presents some suggestions for further investigation.

2. On the importance of innovation networks

As already mentioned, modern economies must cope with a growing globalisation process which changes the competitive environment substantially, imposing on firms to redesign their competitive advantage and reposition themselves in globalised markets. In light of these changes some have argued that globalisation renders the significance of location for economic activity increasingly irrelevant (O’Brien, 1992; Cairncross, 1997; Gray, 1998). However, this opinion is not shared by many researchers who, from different points of view, argue that globalisation actually increases rather than reduces the importance of location, that it endorses economic uniqueness, and that local clusters become increasingly relevant in the promotion and diffusion of innovations (Krugman, 1996; Porter, 1998; Scott, 1998; Fujita, Krugman and Venables, 2000). In the words of Porter, "in a global economy – which boasts rapid transportation, high speed communications and accessible markets – one would expect location to diminish in importance. But the opposite is true. The enduring competitive advantages in a global economy are often heavily localised, arising from concentrations of highly specialised skills and knowledge, institutions, rivalry, related businesses, and sophisticated customers" (Porter, 1998: 90).

Along this line of reasoning, Pyka (2002) pointed out how, following a knowledge-based approach and within an evolutionary perspective, networks of firms can be considered as the central determinant in the creation of industrial novelty. However, the scope of innovation itself should be widened. In other words, product and process innovation constitutes an important, but not the only, type of innovation. Hence, in order to have a full picture of the concept of innovation, one must add to the equation new forms of organisation and the exploitation of new markets (Lundvall 1992; Clarysse et al. 1998).

It is only within this research framework that one could explained the apparent paradox of phenomena like the "economically successful industrial clusters in an age in which new telecommunication systems facilitate the transfer of ever more complex sets of knowledge at an ever-increasing rate" (Pinch et al., 2003: 375), or the spatial concentration of R&D activities in the home base of the innovating firms – defined by Kith Pavit and Pari Patel as *an important case of non-globalisation* (1991).

3. On the case study

Notwithstanding the domination of free trade discourse, the food market still remains one of the most protected sectors. While liberalisation reform take place at almost all levels of the economy, all over the world, the shortcomings of open food markets become gradually apparent. The reaction at the international level is twofold. On the one hand, governments recognise the need to come up with a global food policy. On the other hand, international organisations introduce food standards, with the aim of increasing transparency in the sector (Avermaete and Viaeneon, 2001).

Food safety and quality policies are strategies that aim at assuring the customer that the characteristics of a product or service are consistent with his or her requirements. At the heart of both strategies is technological and organisational innovation and their main objective is to optimise communication within and among the firm in order to guarantee a specific quality. Although food safety and quality are first and foremost a matter of organisation and communication within the company, there is no doubt that both strategies can be best achieved through technological innovations.

The question of food safety guarantees is particularly important for small firms, as they are usually required to provide high guarantees, since retailers do not have enough information on their safety management. One possible way of providing information on the incentives of the company as well as on its a safety system, is delegate its control to an external third party. Indeed, all over Europe, large food retailers put pressure on their small food suppliers to put into practice such safety systems (Avermaete and Viaeneon, 2001).

The ever growing need for high food safety guarantees has also bearings on the development of the organic food market. Although this market is still small, it is growing rapidly in terms of both supply and demand (Michelsen et al. 1999). Food safety concerns and ethical and emotional considerations explain a great deal of this phenomenon.

The processing of organic products represents a special case of innovation in the food industry. In other words, rather than an incremental product innovation or basic process innovations, a company actually repositions itself and its whole product line on the principles of organic production and at the same time keeps its traditional product line (Grunert et al. 1997). Hence, switching to organic production is in itself an innovation which results in the production of an output that better responds to changes in consumers' tastes. However, once switched to organic productions, firms will constantly have to comply with externally defined standards and product characteristics. In turn, this will require a constant innovating and learning capability.

All these consideration makes the food sector, and in particular the organic food production, an interesting case study to investigate innovation and networks formation. As already mentioned we shall calibrate our theoretical model (which will be described in the following section) using data collected from a network of firms directly involved in the production of organic food and a group of formal institutions which support organic production. This network of firms and institutions is located in a backward region in the south of Italy (the province of Foggia).

In the area of Foggia there are 120 organic industrial firms out of which we chose a sample of 32 units selected with the *focus group* technique. This technique provides qualitative information on a specific theme by playing on the interaction and confrontation of points of view expressed by participants in a discussion conducted by a facilitator (European Commission, 1999). In this study case, participants to the focus group belonged to Local Public Institutions, Research centres, Entrepreneurial associations; Certification agencies (i.e. quality control agencies) from which interaction we obtained a draft of the *organic firms' network* whose structures was checked and corrected during the direct survey.

In figure 1 we report the geographical distribution of the 32 firms, a list of the corresponding names, size and belonging province is reported in table 1.

- Insert Figure 1 about here -

Figure 1: Firms geographical distribution

- Insert Table 1 about here -

Table 1: Firms main characteristics

The institutions supporting productive structures and activities of the organic sector consist of 33 units, out of which we chose a sample of 16 institutions. Also formal institutions' relational data were collected with the *focus group* technique in order to obtain the roster of observable actors. This list included also actors external to the Foggia region but whom are still very relevant: from a dynamical perspective the absence of external relations could cause the death of the system due to its small innovative capability (Bramanti and Senn, 1991).

The selected sample is composed by institutions belonging to different areas and therefore performing different supporting activities. In particular we selected: public institutions, training and research centres, development agencies, non profit organizations, certification agencies, business communities, professional associations and environmental agencies. Indeed some of these institutions are, by their nature, content specific meaning that they are involved in specific areas of the production/innovation process carried out by organic firms. This fact implies that some institution collects and provides information on specific areas whereas some others, being broader in scope, provides all sorts of information relevant to organic food production. Simplifying the complexity of institutions categorisation we could suggest a broad distinction into two groups one called *focused institutions* and a second group called *broad institutions*, the former type being specialised in specific areas relevant to organic production/innovation and the latter type being omni-comprehensive in scope. In table 2 we report a complete list of the institutions interviewed and the specific support provided by each institution to organic firms.

- Insert Table 2 about here -

Table 2: Institutions main characteristics

The questionnaire, submitted with face-to-face interviews both to firms and institutions, was structured in two parts. The first part aimed at gathering general information on the characters and location of the firm or institution. The second part aimed to collect information on relations and, more precisely, on the existence or not of ties, their nature and, in the case of communicative relations, the kind of information exchanged. These data were used in an earlier work (Morone, Sisto and Taylor, 2004) and showed how notwithstanding the existence of a rather cohesive network, knowledge and information flows among firms remained a fairly marginalised occurrence. In light of this result we were able to maintain that the existence of a cohesive network was not by itself a sufficient condition for positive externalities associated with knowledge exchange in the surrounding environment and that some policy intervention was required to promote effective knowledge flows.

4. An agent-based model of learning, innovation and geographical proximity

4.1 Rationale for the modelling approach

In the field of evolutionary economics, agent-based modelling is now recognised as one of the most promising new tools of investigation. The agent-based approach allows us to capture dynamics and complexity in our models. This is exactly what is required for studying processes of innovation, firms' partnering, and formation of innovation networks. The objective is to understand better the relations between micro-processes (the decisions and behaviours of economic actors) and the emergence of stylised facts common across much of industry (relating to R&D and the geography of firms) in the model output. Recently there has been significant other research targeting this area, (e.g. Gilbert, Pyka, and Ahrweiler, 2001; Pajares, Lopez and Hernandez, 2003) using agent-based methodologies. Gilbert et al. (2001) suggest that it has proved difficult to analyse innovation dynamics with the traditional analytical tools and suggest as an alternative, the need for "an abstract simulation model that could constitute a dynamic theory of innovation networks" (Gilbert et al., 2001).

In our view, this approach to the problem of innovation dynamics does offer a promising way of modelling some of these processes. The focus of this paper is upon the analysis and management of change in industrial processes, and matters of industrial policy relating to support for regional innovation networks. We suggest that it would be most appropriate to use agent-based modelling in conjunction with case study, experimental and/or microeconomic research. This is important because the findings of simulations based upon formal logic must be supported, both qualitatively and quantitatively, by empirical work. Meanwhile, we wholly agree with Pajares, et al. (2004), confirming the use of agent-based models as a 'wider laboratory' for experimental economics, and in our investigation of the model we follow the same experimental methodology. The experimental set up is discussed in section 5 of this paper. Now, for the rest of this section, we describe the agent-based model.

4.2 Firms, Institutions and social network

This model is based on the definition of two different kinds of agents (firms and institutions) that perform different tasks. More precisely, firms aim at innovating and are, therefore, constantly involved in a learning process which occurs both individually and interactively. Institutions, on the other hand, play a supportive role, facilitating knowledge flows among firms which possess complementary skills. We assume a population of N firms and M institutions (with $N > M$) allocated over a *geographical network* which is situated upon a grid of cells that reflects the geographical configuration of the province of Foggia.

Firms allocated in this geographical network aim at innovating. As already discussed, innovation is defined as the response to rising external pressures. Hence, every time a new product is supplied in the organic food market it matches its demand. Innovation drives the firms' search process and motivates them to partner with other organisations. Since in order to accomplish a new production process, new skills are required, innovating firms will aim at developing such skills and learn how to use them. In this context skills are defined as an applied and agents' embedded dimension of knowledge.

In this model each firm is initially endowed with a *Skills Profile* (SP), defined as a complex and interdependent structure of abilities/competencies that can mainly be acquired through *individual learning* (implemented by firms as a specialised search process which replicates the work of R&D laboratories). Conversely, the process of acquiring new information on skills possessed by other firms and, hence, on the profitability of partnering, occurs through interaction with institutions. In this work we make the assumption that skills are not easily transferred through interactions, i.e. that they cannot simply be diffused from one firm's profile to another. In fact, we assume that *interactive learning* (i.e. flows of skills from one firm to another) can take place only if there is a joint production (i.e. innovation partnership) among two or more firms (this will be explained in detail in section 4.6).

Institutions gather information on firms' *skill profiles* and pass it on to firms that might need this information to jointly-innovate. Each time an institution is contacted by a firm, it gathers information on its *skill profile* and places it in a database. Building up this database allows institutions to be more effective in spreading information on complementary skills possessed by different firms.

As already discussed institutions can be *focused* or *broad* in scope. *Focused* institutions can collects/provide information only on skills related to specific areas whereas *broad* institutions collect and provide information related to any kind of skill.

In our preliminary investigation with an early version of the model we have implemented only the *broad* institution type, and in all experiments reported here we defined a single *broad* institution performing this task (which will be discussed in section 4.6).

The model itself is structured into two separate bodies: there is a set of properties of the *system* and a set of properties of *individual firms* and *institutions*. For the sake of clarity we shall start describing the properties of the *system*, in sections 4.3 and 4.4, and then move on to the properties of the firms and institutions, in sections 4.5 and 4.6 respectively.

4.3 Defining the Firms' Skills Universe

The system is initially endowed with a *Firms' Skills Universe* (FSU), which contains the whole knowledge of the system. In this model, the FSU is represented by a network of nodes and links: nodes in the FSU can be thought of as possible skills or technologies to be learnt by the firms, and links define the requirements of each node. The FSU structure therefore defines the way in which subsequent skills depend upon the prior acquisition of other skills. Using a simple graph notation we can write: *FSU* (Σ, Ψ), where $\Sigma = \{N_0, N_1. . ., N_{MAX}\}$ is the set of skills, and $\Psi = \{\Psi(i), i \in \Sigma\}$ gives the list of requirements to go from one node to another.

The FSU is generated at the beginning of the execution (simulation) of the model from an initial list of x nodes N_1 to N_x (with $x > 1$) which are themselves each linked to the root node, N_0. In the initialisation sequence nodes N_1 to N_x are placed, along with N_0, in a parent list P. Then, the remaining 'child' nodes, i.e. those belonging to the set $\{N_{x+1}, . . ., N_{MAX}\}$, are taken in turn and added to the FSU as follows:

Step 1: determine the number of parents that the child will have (must be an integer between 1 and the dimension of P)
Step 2: select those parents randomly from the set P, and make a link from each one of them to the child
Step 3: for each parent currently in P, with a small probability P_D delete that parent from P
Step 4: add the current child to the parent list P

The process is repeated until all nodes have been positioned in the FSU. Following this specification, there is a small chance that a parent node would be *sterile*, i.e. that there are no dependent child nodes and at this vertex, the FSU reaches a *dead end*.

There is one additional step which gives the FSU a more interesting structure, *Step 5: with a small probability $P_{S,}$ split P into two independent parts. Subsequently, child nodes will be attached to one specific parent list (chosen randomly), from where all its parents will be drawn*

Step 5 causes branching of the FSU such that different areas of it can develop independently. In other words, later nodes are positioned such that they depend on a limited number of earlier nodes that are themselves quite interdependent. This specification is intended to represent the idea that it is feasible for a firm to 'specialise', or to learn some advanced skills without first having to learn almost everything else at a more basic level.

Implementing this in the program involved using a *meta-parent list* which was a dynamic array list of variable dimension. When the original parent list split at some (randomly chosen point), then the truncated part and the second 'splitter' part would then make up the meta list. It is also possible that one of the parent lists could become empty: in this case it would simply be removed from the meta list at the end of that cycle.

In figure 2 we reproduce a representative graph of a *Firms' Skills Universe* composed of 50 nodes (skills).

- Insert Figure 2 about here -

Figure 2: Firms' Skills Universe

For step 1 we used a very simple probability function, in which each node (with the exception of the first five nodes and the root node) will have one parent with probability $p_1=0.6$, two parents with probability $p_2=0.3$ and three parents with probability $p_3=0.1$.

4.4 *Radical innovations vs. incremental innovations*

The system is also endowed with an ex-ante determined *Global Innovation List* (GIL), which represents all the possible innovations, defined by external parties (national, supranational, non governmental organisation, consumers), that can be achieved by firms. All of the potential innovations are generated in the initialisation phase of the simulation, at the same time as the FSU is created. During each iteration where a child node N_i is placed in the FSU, there is a small probability that an innovation is generated.

In this model, the researcher must specify in advance of running the simulation how many innovations there will be in a given experiment, and the corresponding number of node-indices are then selected at random. So, for example in Figure 2 above where there are 50 nodes, the node-indices run from 1 to 50 inclusive. If we specify ten innovations in our GIL, then ten of the node-indices will be chosen, and the innovations will be generated when these corresponding nodes are placed in the FSU. This is not a trivial matter since the innovations are generated from the *current* parent lists during the set up of the industrial environment, according to the following step (Step 6).

The GIL is composed of *m* incremental innovations and *n* radical innovations. The first kind of innovation is always based upon an already existing innovation, and is created by *replacing* one existing skill with a child, or a child of a child, etc. (we should say *closest available descendent*) of that same skill. On the contrary, radical innovations are created by combining a whole new set of skills never used for previous innovations. There is one special case that is the *root innovation* – the very first innovation – which must always be a radical innovation, requiring a new combination of skills.

We define I_t as the set of incremental innovations at the initialisation time, and the single innovation $\psi_t \in I_t$ as a vector of skills. We also define R_t as the set of radical innovations at the initialisation time, and the single radical innovation $\omega_t \in R_t$ as a vector of skills.

Now we can define the GIL, at the initialisation time, using set notation as:

$$GIL_t = I_t \cup R_t \qquad (2)$$

where the set I_t is defined as $I_t = [\boldsymbol{\psi}_\mathbf{1}, \ldots, \boldsymbol{\psi}_\mathbf{m}]$; and the set R_t is defined as: $R_t = [\boldsymbol{\omega}_\mathbf{1}, \ldots, \boldsymbol{\omega}_\mathbf{n}]$. Following on from the algorithm developed in the previous section, we can now add a further step to it.

Step 6: if the node index is one of those randomly selected, generate a new innovation by either (a) INCREMENTAL method or (b) RADICAL method, as described above, and add it to the GIL

Having created the GIL and the FSU at initialisation, the model is then ready to proceed to the main simulation phase where firms' learning and innovation take place. The single objective of firms is to obtain all of the necessary skills to fulfil the requirements of an innovation. The first firm (or group of firms) to attain a particular innovation will be recorded as the *First-Mover* (FM) innovator of that product innovation. In other words, that firm (group) is recognised as the first one to develop and market the product.

In this model, as we are only concerned with the innovation process, and not the emergence of markets for those new products, when the simulation reaches the point where an innovation is accomplished and its FM identified, that innovation will be "tagged" by the innovator in the GIL. Hence, each innovation can be performed only by those firms which perform it first.

As mentioned earlier, innovations may be attained either through searching for partners with complimentary skill attributes, or through individual learning. In order to do so, in each cycle firms have an opportunity to interact as well as to learn individually. To implement this two-fold learning process will involve the use of two nested time-levels. We aim to make explicit the relation between, on the one hand, the time taken to perform individual innovation – the *individual learning cycle* – and, on the other hand, the time taken to locate potential partners, interact with them and carry out joint innovations – *the partnering cycle*. This raises the important question of how to measure the opportunity to search for partnerships – *sharing the burden* – against the opportunity to internalise the innovation process, which may be more beneficial.

4.5 Individual learning and the FSP

Firms are initially endowed with a *Skill Profile* (SP). As already mentioned, the goal of each firm is to innovate. Hence, every cycle, each firm will try to find out which innovation can be performed with the possessed active skills. This is done by comparing the individual firm's SP with the GIL. If one or more innovations can be accomplished with the possessed skills, then the firm will successfully perform them. If no innovation can be performed then the firm will try to acquire those skills which would allow innovating. This can either take place through individual learning or through interactive learning and the definition of partnership for innovating. We will now describe in more detail the individual learning process, and then in the next section we will turn to describe how partnership are established and innovations are performed.

In section 4.3 we defined the FSU as a graph composed of a list of nodes representing skills articulated in a complex and structured way. Individual learning of new skills in the FSU takes place through a search process which goes from less to more specialised skills (i.e. it is a depth-first search). The agent has list of 'child' nodes of those already in its SP, which it systematically tries to learn. Recall that child nodes can be acquired only if all of its parents have been mastered (knowledge demands knowledge in order to be acquired). If the target node cannot be immediately learnt, then the algorithm backs up one level and first tries to acquire all of the parents of that node. Following this procedure, when eventually successful, the agent then moves on to target the children of the just learnt node.

In fact, the algorithm is rather more complicated than it at first seems, for it involves distinguishing between targets (children of the just learnt node) and sub-targets (parents/ancestors of the target). The difference arises because, unless the target turns out to be a leaf node, only the children of targets can be next-in-line targets, whereas other children of sub-targets (that are not parents of the current target) should not be added to the target list, if we wish to carry out a depth-first search of the FSU, as specified earlier.

We shall define three types of firms: small, medium and large firms (considering the data collected in our survey, we categorised firms according to their annual turnover. More precisely we defined small firms as those with a turnover of less than € 500,000; medium firms as those with a turnover ranging between € 500,000 and 5,000,000; finally, large firms as those with a turnover higher than € 5,000,000. This classification is one that was proposed to us by one of the case study participants. Differentiating among the firms and dividing them into three size-groups allows us to specify heterogeneous agents and therefore make our model a better representation of the organic food network case study. According to Table 1, we initialise the model with 5 large firms, 12 medium-sized firms, and 15 small firms. As mentioned earlier, we make the assumption that that a firm's size is positively correlated to its ability to learn new skills. To do so we define an *individual learning rate* parameter which varies according to the size of the firm. A small firm can learn one new skill per cycle, medium firms two and large firms three.

4.6 Interactive learning and firms' partnerships

If the firm is not able to innovate individually, then it will select one innovation from among those not yet accomplished, for which it has one or more of the needed skills, and it will try to partner with other firms and jointly innovate. The selection of the innovation is random, but with the chance of selection of each innovation weighted according to the number of skills of that innovation already possessed.

Joint innovation is composed of two different steps; in the first step the firm attempts to form a partnership from among its neighbouring firms. The *neighbourhood* is defined as the region on the grid that includes those cells adjacent in the four cardinal directions and within the firm's visible range ν (i.e. von Neumann neighbourhood structure). Note that not all the cells of the grid are occupied by agents, and those occupied contain only one firm/institution. Only if the first step does not succeed then the second joint innovation step - that involving institutions - takes place.

So, in the initial step partnering will happen through direct interactions among neighbour firms. Given the importance attributed to geographical proximity in innovation, it seems reasonable to privilege this kind of neighbourhood-based partnering as an initial, and therefore prioritised, step in our model. The benefits of local partnerships accrue mainly not from the easier finding of partners, but rather from the easier integration of complementarities due to the involvement of some degrees of tacitness of knowledge. Firms' neighbourhoods, and their opportunities to partner, are thus defined by a visibility parameter, and their relative positions on the 2D grid. If, combining the skills of the firm and its chosen neighbour, the partnership is able to innovate, then both firms will acquire the complementary skills (interactive learning). If individually the partners each possess some of the required skills, but in partnership they do not possess all of them, then the search process will continue with the firm contacting another of its neighbours, until either the partners can together perform the joint innovation, or until there are no more neighbours to contact. Ultimately, if this is not successful then one of the neighbour firms might work as a link between the firm initiating the interaction and one of its neighbour firms. In this way, firms might create a network of partnerships. However, we leave this intermediate linking arrangement to further exploration: in all our initial experiments we allow only the initiating firm as the contacting (and hence central) firm in the partnership.

In the second step, partnering is facilitated by institutions which, as time goes by, develop a database on the skills possessed by each and every firm that has interacted with them. A firm that cannot innovate individually, or jointly with its own neighbours, contacts the institution and provides a list of skills which are complementary to its own and are necessary to achieve the selected innovation in partnership. The institution then consults its database of firms' SPs, compares it with the list, and then if able to suggest a partner (or partners) with which it would be productive to partner does so. If there is more than one possibility then the suggestion is chosen at random. Whether or not suitable partners can be found, the contacting firm registers its current profile with the institution and the record is added (or updated if not the first contact) to the database.

It is important to mention here that the second step of matching firms' profiles for joint innovation and partnership involves testing every potential partnership arrangement within the neighbourhood of the contacting firm. It will therefore always find a solutions if it exists. Although this assumes 'perfect' ability of firms to match each others profiles, it is reasonable to do so in order to make comparisons with institution-facilitated matching which also has this ability. However, it follows from the model definition that the institution-facilitated partnering is imperfect in that the registered SPs may not be up-to-date (or may not exist in some cases), this in turn can lead to missed opportunities for joint innovation.

5. Some Preliminary Results

In this section we shall analyse some preliminary results, comparing the innovation process which occurs in an environment were firms interact within local neighbourhoods without the support of an institution, with the learning and innovating dynamics promoted by the introduction of a 'broad-in-scope' supporting institution. This will allow us to evaluate how relevant is the role of institutions in terms of overall innovating capability of the whole system as well as in terms of individual performances of small medium and larger firms.

The simulation results were obtained by averaging batches of 12 runs, all initiated with the same parameters and the same configuration. The first set of figures (figures 3-5) present our findings for the case without the institution.

In figure 3 we report the overall innovating dynamics for different values of the visibility parameter (*v*). As it emerges clearly increasing the visibility of the system has no significant effect upon the speed of convergence of the system towards the steady state equilibrium. In fact, for virtually any value of *v* (varying between 2 and 6) the system takes approximately 70 cycles to reach the steady state; moreover, the short term dynamic is pretty much comparable for different values of *v*.

- Insert Figure 3 about here -

Figure 3: Overall Innovation Performance

Industrial system with no supporting Institution

However, some distinctions can be made while comparing industrial systems with different visibilities. If the overall performance is not significantly affected by the value taken by *v* at different model instantiations, there are substantial differences in terms of how the innovations are carried out: basically, high values of *v* encourage the creation of partnerships and, therefore, endorse joint innovations over individual innovations.

It is worth mentioning that joint innovations are, overall, more effective then individual innovations. However, the gap between these two innovating strategies grows wider when the *transparency* of the system (i.e. its visibility) is increased (figure 4).

- Insert Figure 4 about here -

Figure 4: Visibility and Innovation Dynamics

Industrial system with no supporting Institution

What Figure 4 does not show is that there is a great deal of variation among individual simulation runs within each batch. In some simulations the majority of innovations were attained by individual firms, whereas in others the majority of innovations were attained through partnerships, and in either case these majorities could be around 90%. Nevertheless, on average, joint innovations tended to be more numerous than individual innovations.

The increasing relevance of joint innovations over individual innovations has an impact on the network dynamics which, although bounded by firms geographical proximity, results in an emerging network with high number of partnerships. In turn, this impacts positively on the ‘distributions of innovations’ increasing the ‘innovating possibilities’ for small firms as compared to large ones. This can be observed using some basic tools of network analysis. In figure 5 we report a two-mode network in which we represent both innovations and firms’ partnering dynamics. Innovations are represented by black squares and agents by red circles of diameter corresponding to firm size. In Figures 5a and b, the directed links show which firm(s) are involved as an innovator or partner in each innovation.

- Insert Figure 5a and b about here -

Figure 5: Visibility and Partnering Dynamics

Industrial system with no supporting Institution

Figure 5a shows the dominance of a small number of firms in the case v=2. Indeed, 21 out of the total 32 firms were not involved in any innovations. The minority of 11 innovating firms are clearly arranged into network 'components': one large component of four firms, one of three firms, one of two and one consisting of a single firm. The two larger of these components show how some firms interact repeatedly with the same partners, in collaborations that dominate the innovation dynamics and produce highly unequal distributions. Looking at the individual members of the components, it is clear that large firms play a central role, although both medium and small firms are also involved in joint innovations. However, only the large firms attained individual innovations, of which there were just six in this simulation run. In constructing Figure 5a we used the first simulation run (i.e. run 1). Similarly in figure 5b we used the last run (i.e. run 60). It should be pointed out that the first figure was atypical in that it had relatively low number of individual innovations compared to joint innovations: more frequently the result would exhibit a substantial number of individual innovations, on average of about 19 out of a total of 51 for the case v=2, but as mentioned above this was highly variable.

The simulation reported in figure 5b, where v=6, shows a more cohesive and inclusive network, where innovations are spread more equally among firms. There is a single component of participating firms which involves more than half of all firms.

In light of these results we can conclude that increasing the system transparency does not affect the overall performance of the system but increases the participation of small and medium firms to the partnership and, through this channel, it increases their innovating ability. Hence, increasing the system's transparency reduce the concentration of innovating activities generating a more competitive environment.

We can now look at the model with supporting institution and compare these new results with those just analysed. As described earlier, this involves adding a second step in the joint innovation stage in which SP matching is carried out across all potential partner firms in the system. Figure 6 shows how also in this case the overall performance is not affected by different values of *v*. However, after introducing a 'broad' institution the system performs on average much better than before. Even though the long run steady-state is reached in a comparable time span (approximately 65 cycles), the system shows a very different short term behaviour. A sharp rise in the number of obtained innovations is observable from the very beginning of the simulations. It takes, on average, 30 cycles for the system to complete $4/5$ of the possible innovations. Then the system stabilise for about 20 cycles to go up again after the 50^{th} cycle in a smoother fashion until the steady-state is reached.

- Insert Figure 6 about here -

Figure 6: Overall Innovation Performance

Industrial system with supporting Institution

Indeed the sharp improvement in terms of overall system efficiency is due to the introduction of a supportive institution which represents a bridge between any two firms in the network. This, in turn, increases exponentially the number of possible partners for innovations endorsing the creation of several innovating networks. Figure 7 shows how, independently from the value assumed by the visibility parameter, the vast majority of firms jointly innovate through the support of the broad institution. This is due to the fact that now the systems transparency is insured by the presence of a broad institution able to diffuse rapidly and efficiently all information required to find the best partner for innovating.

- Insert Figure 7 about here -

Figure 7: Visibility and Innovation Dynamics

Industrial system with supporting Institution

- Insert Figure 8 about here -

Figure 8: Visibility and Partnering Dynamics

Industrial system with supporting Institution

Examining the corresponding innovation networks, it can be seen that where the institution is present the participation of firms in innovation partnerships is very high. Figure 8 shows the network for the first simulation run (i.e. run 1) where v =2, and in this case all of the firms are involved in at least one innovation. This high participation could be anticipated from the fact that nearly all innovations are attained jointly, and therefore there are more overall opportunities for partnerships in the system. Indeed also in this case large firms play a central role, aggregating around them several innovating partnerships.

6. Final Remarks

In this paper we developed an agent-based model aiming at investigating the innovating dynamics of a small cluster of firms operating in the organic food sector in a backward area in the South of Italy. By means of a calibrated simulation model (yet in a very preliminary stage in this phase of the work) we investigated how a set of 32 firms (heterogeneous in the size) partner together in order to carry out innovation activities defined as a unique combination of ‘skills’. Firms operating in this system could innovate both individually or jointly. In our first set of simulations joint innovations were performed only with neighbouring firms, and we investigated the impact of varying the neighbourhood sizes. We then compared these results with the case where a second joint innovation step was added by introducing an institution agent. In this second set of simulations, if neighbouring firms could not perform any joint innovation they were permitted to contact the supporting institution seeking help. The role of institution in this model was to put in contact firms which had some skill complementarities useful for innovation.

A striking result of our model was that just one ‘broad’ supporting institution could drastically increase the speed of convergence of the system towards the long-run steady state. Moreover, the introduction of a supportive institution increased dramatically the number of possible partners for innovations endorsing the creation of several innovating networks. This, in turn, increased the participation of small and medium firms to the partnership and, through this channel reduced the concentration of innovating activities generating a more competitive environment.

This initial investigation has provided us with an understanding of the dynamics of networks of firms’ partnerships and of the impact of ‘broad’ institutions. However, the one institution that was defined turned out to be more effective than we had expected. Considering the empirical scenario which showed low levels of knowledge flows in Foggia, even in the presence of a large network of formal institutions, it seems that further calibration of the model is required in order to capture this baseline target. Thus, further development of the model will take into consideration the disaggregated data concerning the geographical dispersion of firms and institutions, as presented in Figure 1, (which might provide significant barriers to information flows) and the role of institutions in providing information and putting firms in contact, which Table 2 makes explicit.

Figure 1: Firms geographical distribution

N.	INTERVIEWED FIRMS
1	AZIENDA AGRICOLA DOTT. CACCAVO
2	CIPAM SCARL
3	COSEME SRL
4	EMMAUS SOC. COOP.
5	LA NUOVA ARPI SCARL
6	LA QUERCIA SCARL
7	ANGARANO SRL
8	BIOFACTORY SAS
9	DI TUCCIO RAFFAELE
10	JOLLY SGAMBARO SRL
11	PARADISO TOMMASO & C. SAS
12	PUGLISSIMA SRL
13	SANTO STEFANO SRL
14	BANDB SRL
15	NAPPI SRL
16	OLEIFICIO SAN SALVATORE SNC
17	ORTODAUNIA SRL
18	CI.SEME SNC
19	FRANCO LA DOGANA & C. SAS
20	EUROAGROALIMENTARE
21	MOLITORIA NUSCO SRL
22	SARACINO MIRIAM
23	SANTACROCE
24	CANTINE VINARIS SAS
25	DONNALISA SRL
26	OLEIFICIO LE FASCINE SRL
27	OLIVETO BELMONTE DI BALDASSARRE A.
28	SPIAVENTO SRL
29	D'ARIES ANTONIO
30	L'AGRICOLA PAGLIONE
31	IL PARCO DI CASTIGLIEGO MARIA
32	SOTTO LE STELLE DI PALLADINO R.

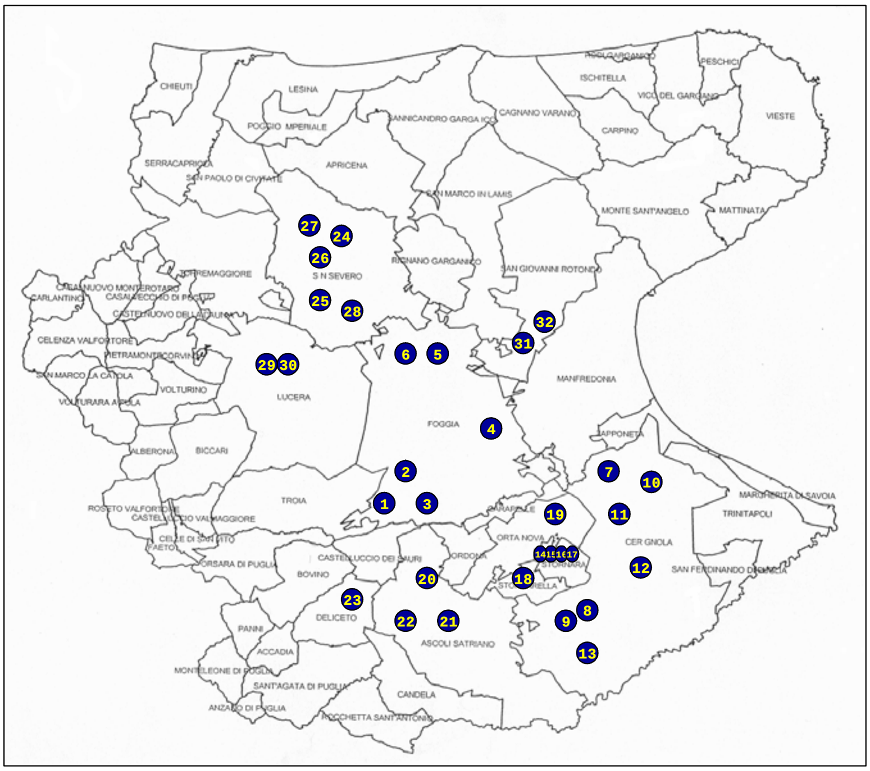


Table 1: Firms main characteristics

N.	Interviewd Firms	SEDE	>500,000 €	between 500,000 and 5,000,000 €	between 5,000,000 and 10,000,000 €
1	AZIENDA AGRICOLA DOTT. CACCAVO	Foggia		x	
2	CIPAM SCARL	Foggia		x	
3	COSEME SRL	Foggia		x	
4	EMMAUS SOC. COOP.	Foggia	x		
5	LA NUOVA ARPI SCARL	Foggia	x		
6	LA QUERCIA SCARL	Foggia	x		
7	ANGARANO SRL	Cerignola			x
8	BIOFACTORY SAS	Cerignola			x
9	DI TUCCIO RAFFAELE	Cerignola	x		
10	JOLLY SGAMBARO SRL	Cerignola	x		
11	PARADISO TOMMASO & C. SAS	Cerignola	x		
12	PUGLISSIMA SRL	Cerignola	x		
13	SANTO STEFANO SRL	Cerignola		x	
14	BANDB SRL	Stornara		x	
15	NAPPI SRL	Stornara		x	
16	OLEIFICIO SAN SALVATORE SNC	Stornara			x
17	ORTODAUNIA SRL	Stornara		x	
18	CI.SEME SNC	Stornarella		x	
19	FRANCO LA DOGANA & C. SAS	Orta nova	x		
20	EUROAGROALIMENTARE	Ascoli Satriano	x		
21	MOLITORIA NUSCO SRL	Ascoli Satriano		x	
22	SARACINO MIRIAM	Ascoli Satriano		x	
23	SANTACROCE	Deliceto	x		
24	CANTINE VINARIS SAS	San Severo	x		
25	DONNALISA SRL	San Severo			x
26	OLEIFICIO LE FASCINE SRL	San Severo		x	
27	OLIVETO BELMONTE DI BALDASSARRE ANGELICA	San Severo			x
28	SPIAVENTO SRL	San Severo	x		
29	D'ARIES ANTONIO	Lucera	x		
30	L'AGRICOLA PAGLIONE	Lucera		x	
31	IL PARCO DI CASTIGLIEGO MARIA	San Giovanni R.	x		
32	SOTTO LE STELLE DI PALLADINO RACHELE	San Giovanni R.	x		

Table 2: Institutions main characteristics

Name	Kind of institution	Scope	Description
Regione Assess. Agricoltura uff. IPA	public Institution	Broad	Provides general information on policy issues of agricultural and rural development. It prepared a blueprint on organic farming techniques. Provides information on how to protect plantations from disease according to organic standards. Could, in some cases, put firms in contacts among themselves.
Provincia Assess. All'Agricoltura	public Institution	Broad	Provides general information on policy issues of agricultural and rural development. It prepared a blueprint on organic farming techniques. Provides information on how to protect plantations from disease according to organic standards. Could, in some cases, put firms in contacts among themselves.
CCIAA	public Institution	Broad	Specialised in organic food promotion. Could, in some cases, put firms in contacts among themselves.
Università di Foggia	public Institution	Broad	Carries research projects on food, tests products to be used for organic production, develops new varieties of organic products, carries market analysis. Works as a link among firms.
Ist. di Cerealicoltura	training and research centre	Broad	Carries research projects on organic new varieties of organic products, carries market analysis. Works as a link among firms.
Patto territoriale Agricolo di Foggia	development agency	Broad	This developing agency created to provide financial support to organic firms aiming at improving their capital assets endowment. Does not work as a link among firms.
AIAB	non profit organization	Focused	Certification agency for organic food production. Unofficially provides technical information on organic food production. Works as a link among firms.
Daunia & Bio	non profit organization	Focused	Organic food producers' consortium created to retail organic products. Works as a link among firms.
Biogargano	non profit organization	Broad	Organic food producers' consortium. Unofficially provides technical information on organic food production. Works as a link among firms.
ICEA	certification agency	Focused	Certification agency for organic food production. Unofficially provides information on organic farming. Works as a link among firms.
QCI	certification agency	Focused	Certification agency for organic food production. Unofficially provides information on organic farming. Works as a link among firms.
CIA	business consortium	Broad	Develops projects for new firms which aim at switching to organic food productions. Provides technical assistance to these new firms. Could, in some cases, put firms in contacts among themselves.
CONFAGRICOLTURA	business consortium	Broad	Develops projects for new firms which aim at switching to organic food productions. Provides technical assistance to these new firms. Could, in some cases, put firms in contacts among themselves.
Consorzio bonifica del Gargano	professional association	Broad	Organic food producers' consortium. Does not provide technical information. Does not work as a link among firms.
Legambiente	environmental agency	Broad	Organises promoting activities (such as fairs). Does not provide technical information. Could, in some cases, put firms in contacts among themselves.
Agronomi	professional association	Broad	Carries research projects on new varieties of organic products. Provides technical assistance to new firms. Could, in some cases, put firms in contacts among themselves.

Figure 2. Firms' Skills Universe (FSU)

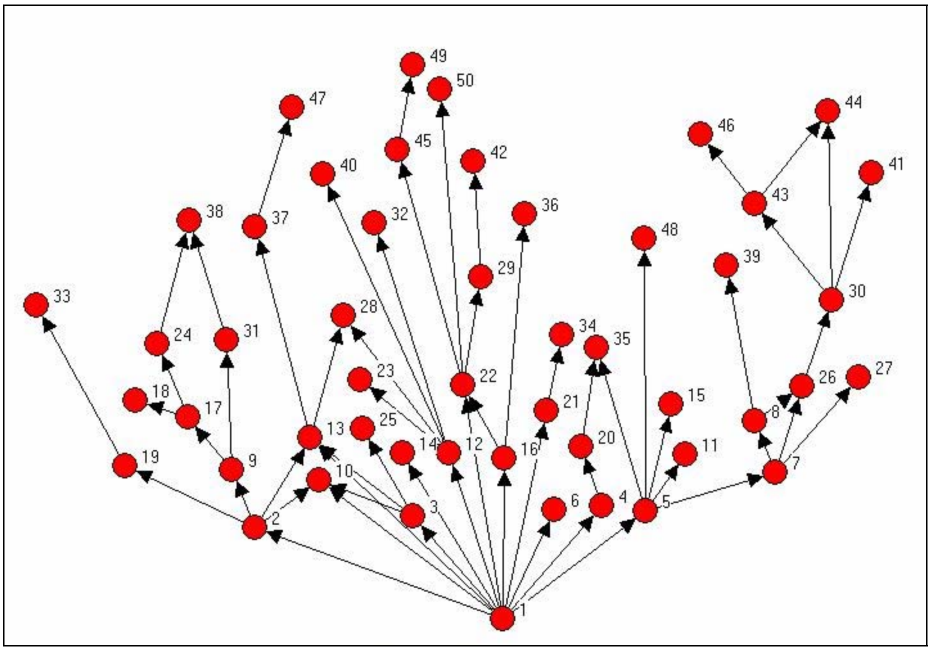


Figure 3

Total Innovation Dynamic

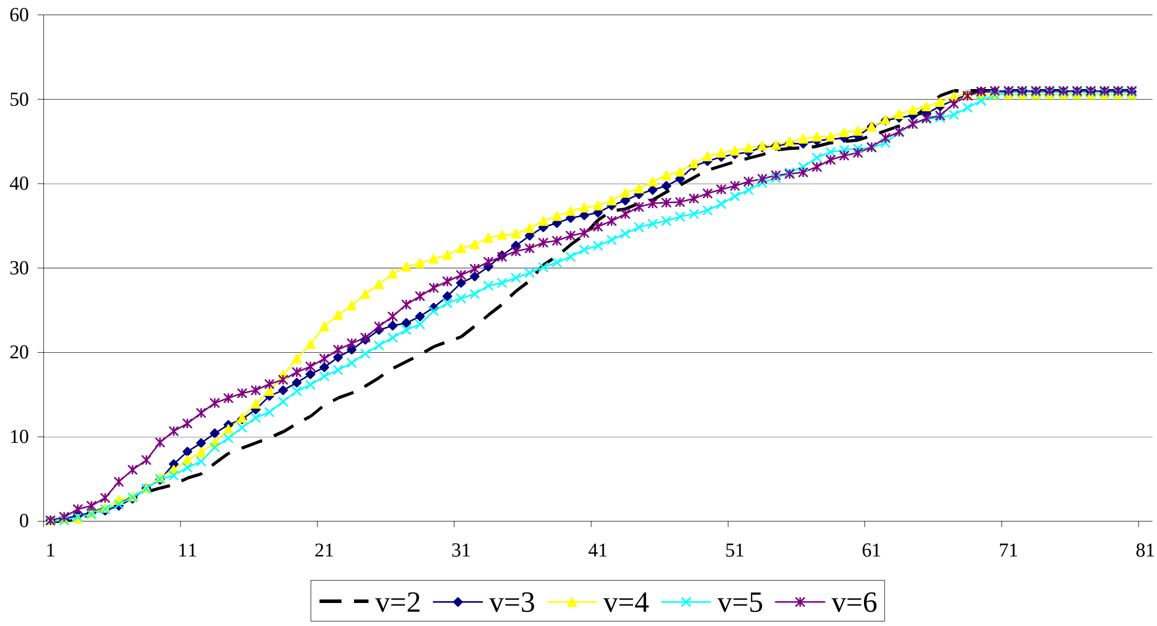
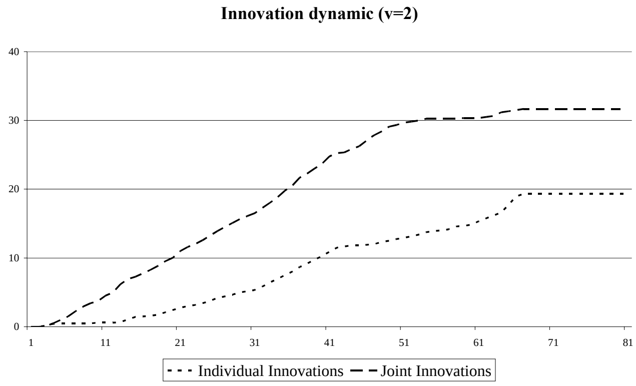
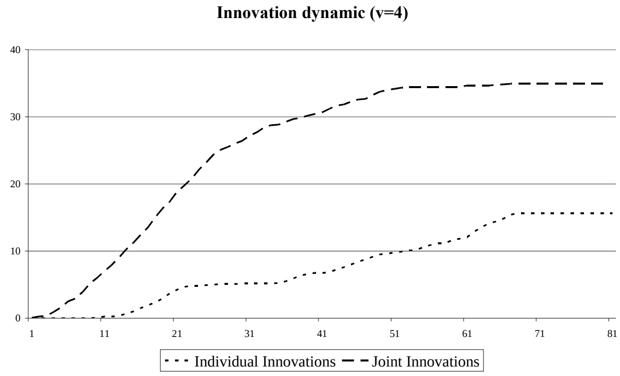


Figure 4





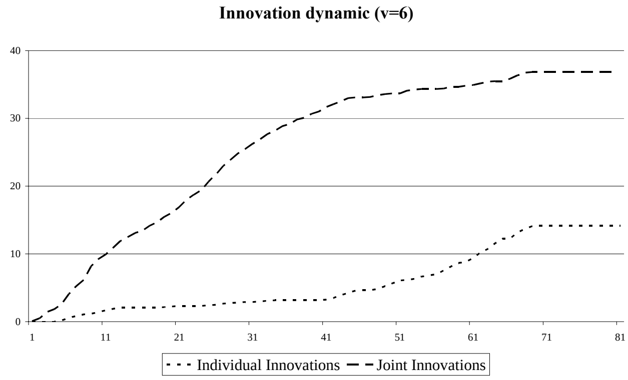


Figure 5a

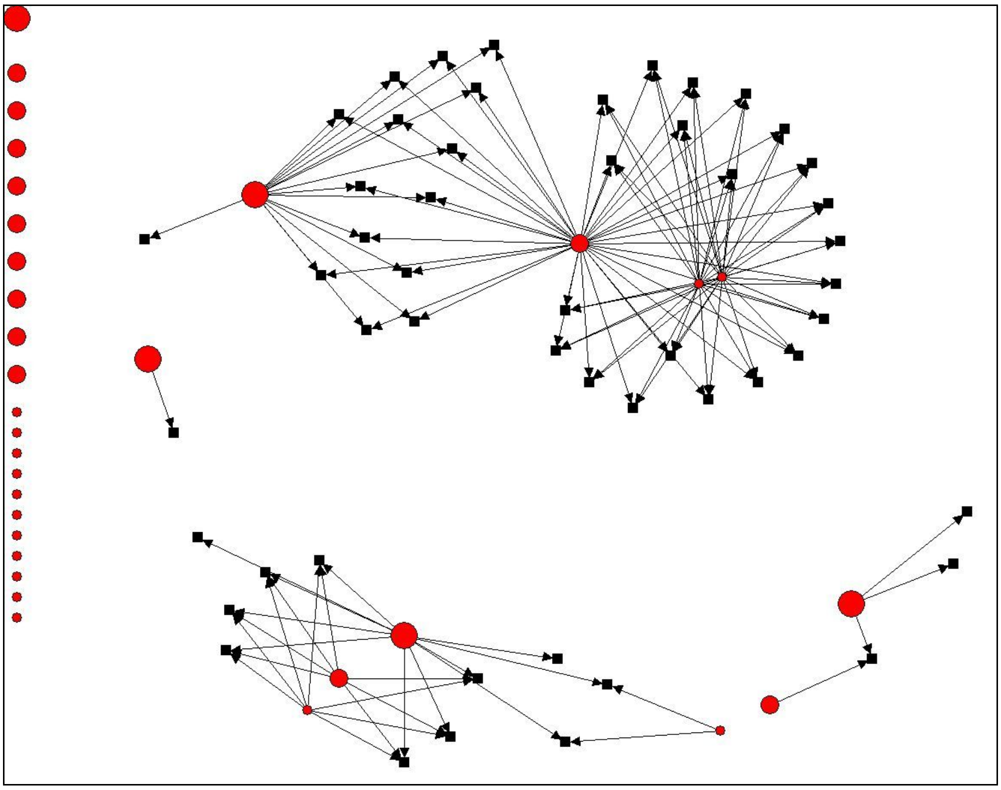


Figure 5b

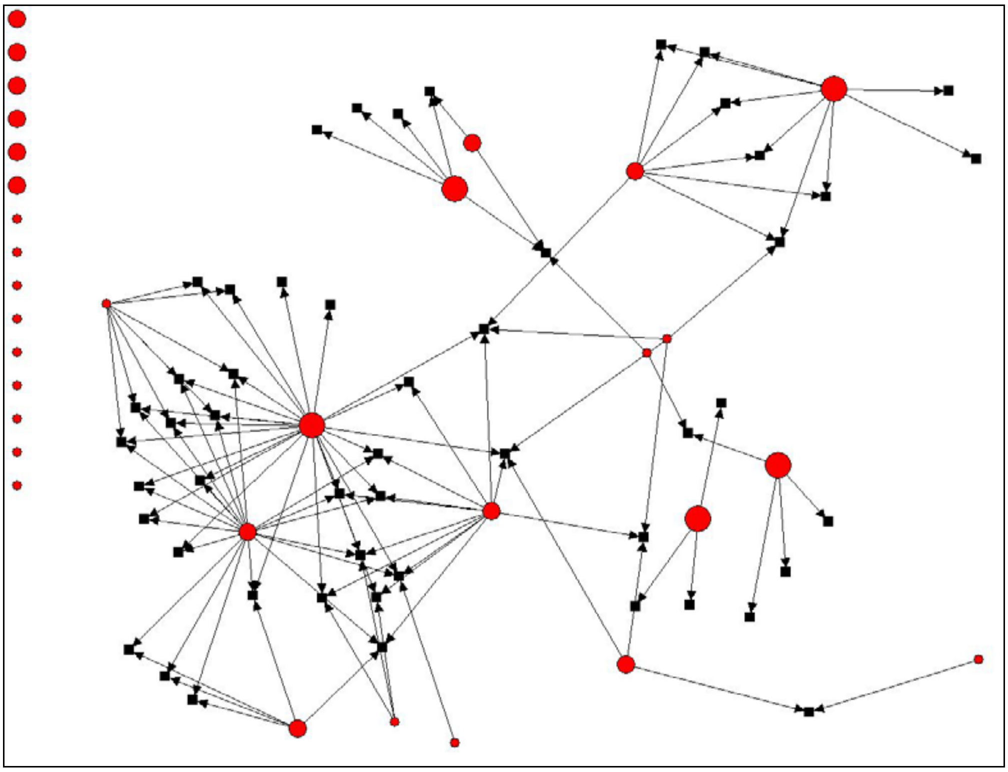


Figure 6

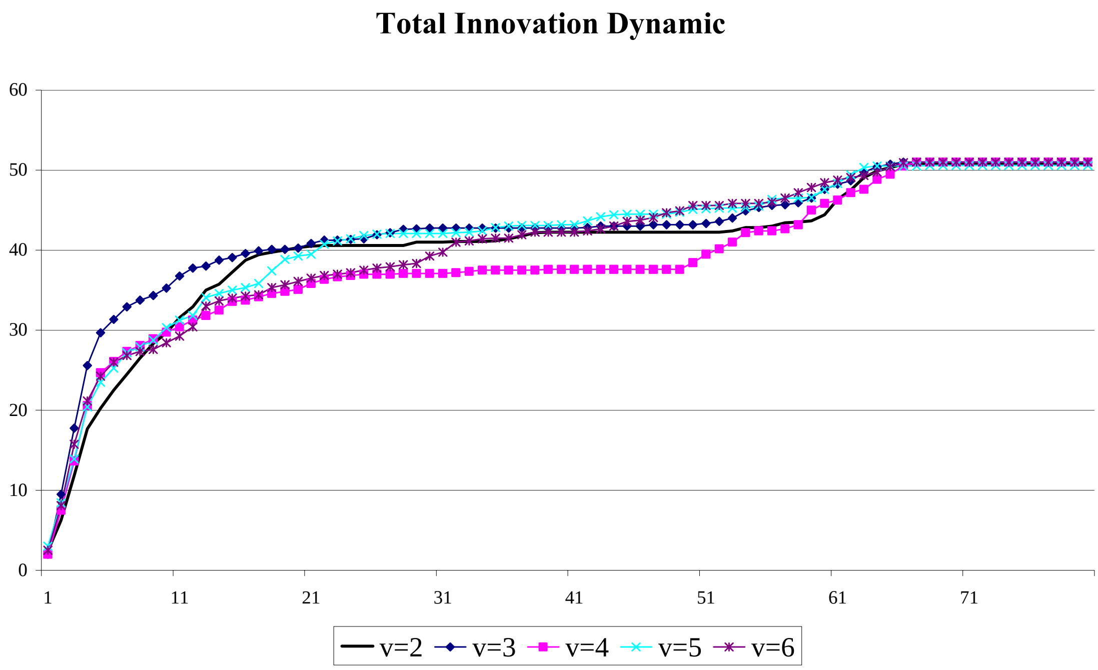
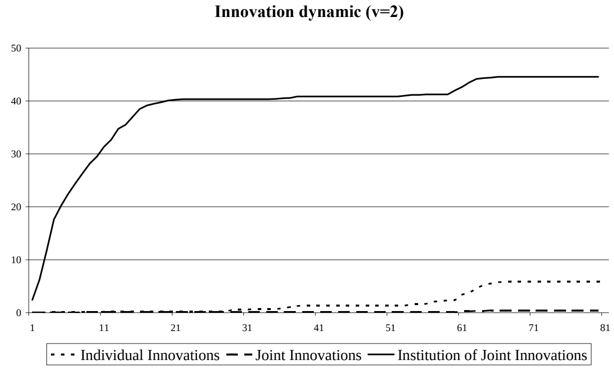
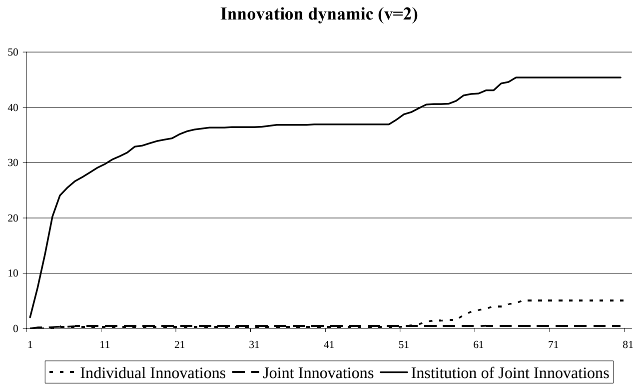


Figure 7





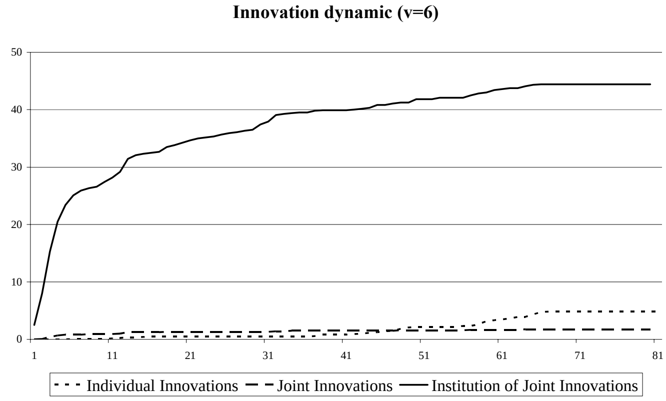
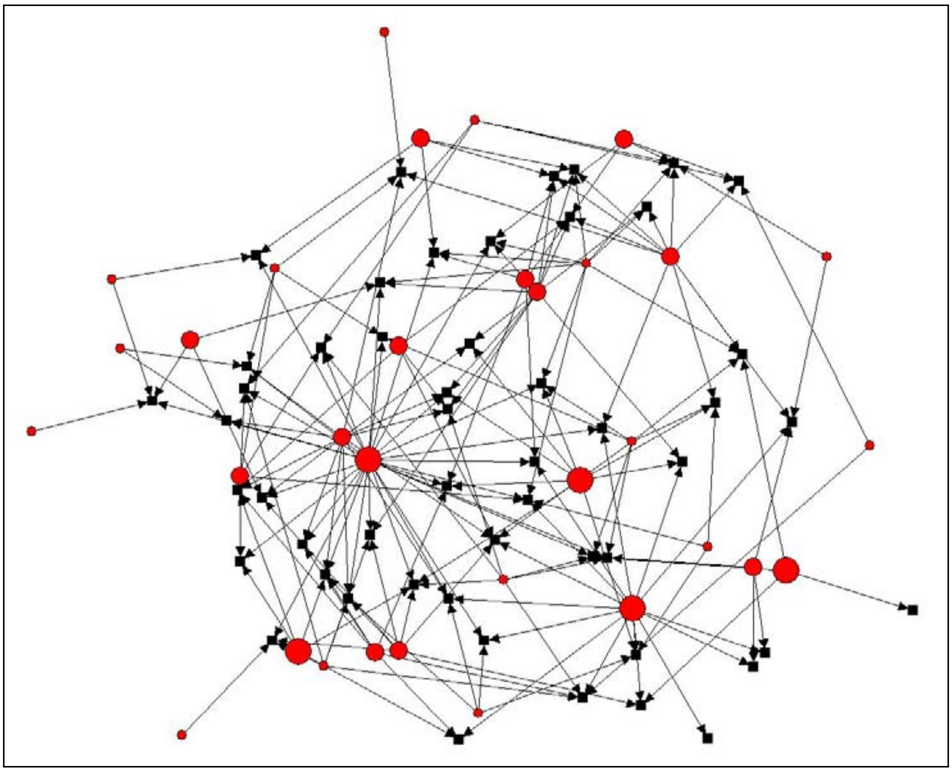


Figure 8



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