http://www.e-jemed.org/

ISSN : 1298-0137

e - JEMED
The Electronic Journal of Evolutionary Modeling and Economic Dynamics

Article number: 1028

Riccardo Boero and Flaminio Squazzoni, Proximity Relations, Partnership Structure and Supporting Institutions in an Agent-Based Prototype of Industrial Districts, The Electronic Journal of Evolutionary Modeling and Economic Dynamics, 1028, http://www.e-jemed.org/1028/index.php

---

Riccardo Boero

LIASES, Faculty of Economics, University of Turin, Italy

Flaminio Squazzoni

Department of Social Sciences, University of Brescia, Italy

Abstract

Industrial districts (IDs) are complex systems based on an evolutionary network of interactions among heterogeneous, functionally integrated, complementary and localised firms. The paper describes an agent-based model of IDs that allows to investigate some theoretical hypotheses on the relation among behavioural styles of ID firms, different forms of proximity and of inter-firm relations, and their effect on technology and market adaptation of the ID as a whole. Moreover, we focus on some hypotheses on the role of partnership externalisation and the function that supporting institutions can exert as scaffolding structures able to improve effective connections between the ID and external environment.

Keywords: Agent-Based Models, Industrial Districts, Technological Change, Proximity Relations, Supporting Institutions

JEL: C63; O33; R12

Proximity Relations, Partnership Structure and Supporting Institutions in an Agent-Based Model of an Industrial District Prototype

Riccardo Boero

LIASES

Faculty of Economics

University of Turin, Italy

e-mail: boero@econ.unito.it

Flaminio Squazzoni

Department of Social Sciences

University of Brescia, Italy

e-mail: squazzon@eco.unibs.it

Abstract

Industrial districts (IDs) are complex systems based on an evolutionary network of interactions among heterogeneous, functionally integrated, complementary and localised firms. The paper describes an agent-based model of IDs that allows to investigate some theoretical hypotheses on the relation among behavioural styles of ID firms, different forms of proximity and of inter-firm relations, and their effect on technology and market adaptation of the ID as a whole. Moreover, we focus on some hypotheses on the role of partnership externalisation and the function that supporting institutions can exert as scaffolding structures able to improve effective connections between the ID and external environment.

JEL: C63; O33; R12

Key Words: Agent-Based Models, Industrial Districts, Technological Change, Proximity Relations, Supporting Institutions.

* Corresponding Author: Flaminio Squazzoni, Department of Social Sciences, University of Brescia, Via San Faustino 74/B, 25122 Brescia, Italy.

The paper shows an example of how agent-based models (ABMs) can be used to investigate some theoretical questions in the field of IDs. The first section stresses the utility of a complex theory-based approach to IDs and the need of some new modelling techniques, such as ABMs, which allow to formalise and synthesise different pieces of empirical and theoretical evidences. The second section shows some hypotheses on IDs functioning that we investigated through ABMs simulations.

The third section sketches how the ID prototype works[1]. The fourth section shows some simulation settings that we created to investigate the role that different behavioural styles, undertaken by ID firms, play on the generation of different ID interaction structures. For "behavioural style" we mean that behaviour of ID firms, which need to be conceived as agents with bounded rationality, is mostly related to a belief systems and some consequent assumptions about how individual goals (improvements of performance) can be reached.

The fifth section shows other simulation settings that we created to investigate the role that partnership externalisation and supporting institutions play on the evolution of ID structure over time and on technological adaptation of ID as a whole.

The sixth section suggests some closing reflections on the hypotheses previously formulated in the perspective of the simulation outcome.

1. Introduction: Towards an ABM Approach to IDs

Complex system theory approach and ABMs are useful tools to deal with some traditional questions in the field of IDs.

IDs may be defined as complex systems (Lane 2002), because they show all the fundamentals that characterise what can be labelled as "complex adaptive systems" (Arthur, Durlauf, Lane 1997): localised bounded rational agents, interdependence among agents, decentralised interaction mechanisms, nonlinear aggregation mechanisms, decentralised intelligence and information processing, emerging dynamics, structures as processes, and so on (Auyang 1998; Lane 1993).

A well-accepted basic definition of IDs is the one that follows: IDs are evolving networks of interaction among heterogeneous, localised, functionally integrated, and complementary firms. Firms are embedded into a specific geographical area, they produce one-product goods for the market, according to a division of labour based on production segmentation, specialisation complementarity and mechanisms of production coordination and integration (Becattini 1990; Brusco 1982; Bellandi 2002). The ID logic of organisation should be defined as a complex one, because it conforms to a "heterarchy" (Stark 1999), that is to say neither a pure market nor a pure hierarchy. The ID organisational mechanism IDs relies upon proximity-based spatial and organisational relations of partnership and interdependence among firms, rather than on simple market prices coordination or well-defined hierarchical organisational structures among firms (Boari and Lipparini 1999). This implies the need to understand how these relations evolve over time, how they become relevant carriers of information and coordination for ID firms, how they come to affect ID firms behaviour, how spatial and organisational inter-firm interactions affect

[1] We use the term "prototype" in the sense given by Hofstadter (1979). The term "ID prototype" means that the model focuses neither a specific and real ID, where the modeling operations aim to reproduce a specific reality in a more or less exhaustive way, nor an "abstraction", which concerns fundamental mechanisms of social systems, where the modeling operations attend to study some properties of social phenomena, as it happens, for example, with game theory models, and so on. The term means that we investigated some theoretical mechanisms being seen in action within a specific family of phenomena, namely that of IDs, synthesising them into an ideal-type model.

technological and market adaptation performance of ID firms and the evolution of IDs over time.

From a modelling point of view, as it is known by all the practitioners of ABMs, it is very difficult, if not impossible, to deeply investigate such issues with traditional analytical tools, such as mainstream economic models. Rather, more flexible and qualitative tools are needed to incorporate empirical and theoretical evidences.

Our opinion is that ABMs are, for the time being, the only way to study complex systems such as IDs, from a micro-macro evolutionary modelling point of view. This is because ABMs allow to take into account both the problem of heterogeneity and autonomy of ID agents, the relevance of their temporal-spatial dynamic relations and the emergent evolutionary nature of collective phenomena. Here, for ABMs we mean a computer-based way of formalising socioeconomic evolutionary models, using the computer as an "experimental laboratory" for generating, controlling, manipulating and testing relevant hypotheses about phenomena that are conceived as complex (Epstein, Axtell 1996; Gilbert and Terna 2000). Using principles of Distributed Artificial Intelligence, ABMs allow to model phenomena, starting from well detailed micro-foundations, which describe rules of actions and interaction undertaken by heterogeneous agents. Moreover, they allow to focus on evolutionary dynamics emerging from interaction context, within which agents are embedded and on ways through which emergent properties impact agents adaptation paths and behaviour. Moreover, agent-based computational analysis allows to integrate multidisciplinary concepts, that are useful for understanding complex phenomena such IDs into a coherent framework, but that cannot be well interconnected sticking on a self-referential disciplinary point of view (Conte, Hegselmann, Terna 1997).

From the internal point of view of ID literature, ABMs are needed for different but inter-related reasons. First of all, they are needed in order to deeply understand what scholars call the "ID effect", an emergent externalities-driven mechanism that depends on the nonlinear aggregation and composite nature of IDs (Signorini 1994; Molina Morales and Martinez-Fernandez 2003). Secondly, they are needed in order to avoid the trap that occurs when, into the model architecture, right from the start, an idealtypical and homogeneous behaviour of ID firms is assumed, as the traditional literature about IDs does, when speaking about natural commitment, cooperation, trust among firms as a by-product of the so-called "cultural homogeneity" of IDs (see right criticisms to the ID mainstream school on this point suggested by: Lazerson and Lorenzoni 1999a, 1999b; Staber U. 2001a, 2001b). Last but not least, they are needed to grasp the complex relation between agent-based level, characterised by heterogeneity and diversity, and network typology of IDs, characterised by organising collective features, directly focusing on the importance of dynamic interaction mechanisms (Lane 2002).

2. Issues to Investigate

Using the ID Prototype and running different simulation settings, we focus on the following issues to investigate:

H1) The role of proximity metrics as carriers for learning of ID firms

a) Assumptions

As it is well known in the literature on IDs and clusters, proximity relations among firms matter, as a source of information and a tool of mutual learning (Cooke 2002; Porter 1998). Usually, they are investigated with a network-based perspective, while the relation between micro level of agents and aggregate dynamics of proximity has been forgotten in the background. Recently, some case-studies have shown that proximity relation has different metrics, and especially spatial and organisational ones (Caniêls and Romijn 2001).

According to such a perspective, it is possible to assume that organisational proximity has to deal with direct production interactions among firms, production partnerships and coordination, and so on, no matter how firms are spatially located. In a decentralised system such as an ID, organisational proximity relations work as a tool for production coordination and diffusion of information, that is relevant for production organisation, chain management, and investments coordination among firms (i.e., technological features). Otherwise, it is possible to assume that spatial proximity has mainly to do with co-localisation and embeddedness of firms into the same geographical and social space, no matter if they are part of the same production process. In the case of IDs, spatial proximity relations work as a tool for a mutual monitoring among firms and for an exchanging of information that is relevant for specialisation and technology investments imitation. If the organisational proximity is supposed to be changing over time and to be a locus of cooperation, the spatial proximity is supposed to be relatively fixed over time and to be a locus of imitation-based competition.

Thus, proximity relations need to be conceived as a web of different and overlapping sources of information and learning, which wraps up ID firms. Considering that the relevant information, which circulates within the proximity web, concerns mostly technology features and strategic investment choices of ID firms, these metrics can be viewed as overlapping sources of information that ID firms can exploit with the same aim, that is to say to choose investment courses. The overlapping of proximity metrics may cause redundancy of information and an overloading effect upon ID firms strategic choices. If organisational and spatial proximity relations are always considered at the same time as sources of information, and given the dynamic nature of proximity relations, such a decisional trap could often be at work, affecting the capabilities of firms to undertake a sequential and rational course of technology investment, where for "sequential and rational" phase we mean the linear articulation of phases of exploration, exploitation and saturation of the technology used, as it is outlined in the literature on technological innovation and organisational adaptation (March 1991).

b) Hypotheses

The fact that proximity relations become a real and stable carrier of learning for firms strongly depends on the structure of inter-firm relations. In condition of instability of production relations and weakness of organisational ties among firms, the ID firms spatial proximity is expected to be heavily used as a source of information and, at the same time, continuous interactions with different partners, characterised by different technological individual characteristics and different production requirements, are expected to produce an overloading effect upon the course of technology investments and potential conflicting features of information ID firms should consider. Given that technological learning implies a sequential and coherent course of investment, strong organisational ties and stable organisational proximity relations are a tool of coordination, based on the direct mutual learning among interacting firms. During phases of technological innovation and exploitation, the fundamental interdependence among ID firms, which is the core mechanism of the production segmentation of IDs, needs to be coupled with strong organisational ties able to allow ID firms to coordinate technology investments. The ID organisational mechanism hides, in fact, a context of fundamental interdependence among firms, because nobody alone can cover all the different production phases, needed to complete a final good suitable for the market. During technology phases, spatial proximity relations lose relevancy and organisational proximity relations are more important.

In conclusion, the hypotheses to be investigated are as follows: in an unstable ID context of interaction, proximity relations metrics can conflict and negatively affect technological learning of firms; stable partnership structures and strong organisational ties are needed for coordinating technological investments and learning paths among firms and this is due to the context of interdependence among firms that is the core mechanism of IDs.

H2)The role of different kinds of leaders behaviour

a) Assumptions

ID firms can behave according to different behavioural styles. For "behavioural style" we mean that behaviour of ID firms, which need to be conceived as agents with bounded rationality, is mostly related to a belief system and some consequent assumptions about how individual goals (improvement of performance) can be reached. We assume a stylisation of behaviour according to two different styles. The first one conforms to a "pure market" style of behaviour. The belief system of ID firms is based on the idea that the improvement of economic performance is an individual problem and derives from a continuous optimisation in the choice of transaction partners. It follows that the selective criteria of interaction are based on an individual economic outlook. In this case, behavioural style mostly conforms to the theory of rational choice and the classic image of *homo oeconomicus*. The second one conforms to a "cooperative style" of behaviour. The belief system of ID firms is based on the idea that the improvement of economic performance is a collective problem and derives from the search for a stable structure of cooperative interaction among partners. It follows that the selective criteria of interaction are based on collective technology learning management and the idea that production chains are partnership structures through which agents learn from each others and coordinate each others. In this case, behavioural style conforms to the organisational theory of cooperative agents.

B) Hypotheses

The fact that proximity relations can become carriers of technological learning of ID firms depend on the behavioural style undertaken by ID strategic firms, and namely by final firms that have the specialised function of managing the ID production partnership. Strong organisational ties can be created only by firms behaving according to a "cooperative" style. Otherwise, optimising agents come to produce an unstable set of relations that can cause problems such as those mentioned in *H1*. Unstable production interactions imply an ever changing and a potentially conflicting set of information, trapping firms into schizophrenic investment paths and a lose of investment rationality. In conclusion, the hypothesis to investigate is whether the difference of behavioural styles at micro-level is the core mechanism that explains the emergence of different ID structures and different dynamics of proximity relations.

H3)The impact of the possibility of production externalisation and of the presence of supporting institutions able to effectively link the ID with the external environment

a) Assumptions

The externalisation of partnership relations towards the external industry is a phenomenon that is under discussion in the literature (Corò and Grandinetti 2001). The impact of externalisation on ID firms adaptation and IDs evolution over time is quite unclear. In fact, in the reality, there are both cases of success and failure of externalisation. Externalisation can improve the adaptation capabilities of ID firms and the evolutionary path of the ID as a whole, or rather can destroy the ID as a system of cumulative capabilities.

b) Hypotheses

Externalisation can be a good strategy for ID firms, but only if it is not just realised as an individual strategy pursued by a single firm. In such a sense, externalisation needs to be supported by scaffolding institutions able to monitor the evolution of the industry system, to give relevant technological information to ID firms, to partially re-enforce partnership contracts and to make the strategy a collective managed effort. Otherwise, externalisation could just produce a loss of resources and a risk for the robustness of the ID as a whole, rather to represent an adaptation resource.

3. How the ID Prototype Works[2]

As we stressed since the beginning, speaking about an ID prototype means to translate a general and abstract representation of an ID archetype into a computational architecture. From an agent-based perspective, ID architecture is reproduced starting both from a micro-level of functioning, that is a set of rules describing schema of action undertaken by ID firms, and a network-level, that is a level reproducing the interaction context functioning. What is simulated is the dynamic relation of co-determination among these two interrelated levels. It is a relation that has to be observed from an evolutionary emergent properties perspective of analysis.

We start from a very broad and accepted definition of what an ID archetype is: an ID is a *complex system based on an evolutionary network of interactions among heterogeneous, localised, functionally integrated and complementary firms*. Firms are embedded into a specific geographical area. They produce one-product good for the market according to a division of labour embedded into complementarity-based production segmentation and into mechanisms of inter-firm coordination and production integration.

To reproduce the ID organisational architecture, we have classified a composite population of localised firms into different classes of agents, according to the competence-based complementarity that underlies a division of labour among ID firms. Consequently, we have designed the topology of inter-firm relations, which represents the context not only within which agent moves, but also that agent contributes to dynamically change through action.

We assume that firms are ID agents. They are 400, divided in two different classes: final firms, having functions of organising production and selling goods for the market, and sub contracted firms, having functions related to the phases of production process. The class of sub contracted firms is further divided into three sub-classes, sub firms A, B, and C, that specialise into specific production phases. Thus, we assume that technology allows to segment the production process into four different phases (see Squazzoni and Boero 2002).

The segmentation of the ID production process is obviously re-aggregated in the production chain, the core of inter-firm production coordination (Carbonara, Giannoccaro, Pontrandolfo 2001). In our prototype, we assume that a production chain needs to be composed by one final firm, one subcontracted firm A, one sub B and one sub C. Final firms need an heterogeneous team of three subcontracted firms, specialised in specific and complementary production phases (A, B, C), for assembling and selling the final product on the market. Subcontracted firms need final firms for selling their part of product/process. The interaction mechanism follows: the rule that over simulation cycles, ID agents can produce and sell just one product at the same time,

[2] The ID prototype has been created using the SWARM libraries and Java programming language. SWARM is a toolkit for agent-based simulations developed at the Santa Fe Institute that is used by a growing community of social scientists (see: www.swarm.org). To obtain the simulation code, please write to authors.

therefore taking part to just one production chain at the same time. Moreover, we assume that simulation cycles are scheduled as production cycles.

As it is common belief in ID literature, final firms are central players or focal actors of IDs (Albino, Garavelli, Schiuma 1999; Lazerson and Lorenzoni 1999a, 1999b). They receive orders directly by the market, and they move inside the ID as organisers of production, aggregating subcontracted firms and giving rise to production chains. Consequently, they need to be viewed as synthesising agents, in the organisational sense. The strategic role of final firms is that of being interstitial agents located at the edge of the internal ID structure and the external environment. Thus, they are the fundamental source of adaptive innovation of the ID as a whole. Final firms are the antennas of the ID, directed towards technology and market environments, the only agents that have a complete vision of the production process and the outcome as a whole (Belussi and Gottardi 2000; Boari and Lipparini 1999; Lissoni 2001; Lombardi 2003a; Pilotti 2000; Rullani 2003).

Firms have three basic features: technology (input), organisational asset (throughput), and economic performance (output). Monitoring them, they undertake their course of action. Their goal is to improve their economic performance, making technology investments and trying to adapt their organisational assets to technological market requirements.

The evolution of technology and of market environment is conceived as the selective mechanism impacting ID firms. We have modelled technology and market environment dynamics, and the dynamic relation between market requests and production technology features embodied by firms. Over 2,000 simulation cycles, ID firms are affected by a transition among three different technological regimes (T1, T2, and T3), with growing production costs sustained by firms and growing performance values shaped by the market. The evolution of market and technology is exogenous, as though it was fixed outside by an external standard. ID firms need simply to adapt: they are dependent, in a technological sense, by the environment, and it is nothing but a theoretical reduction that conforms both to common ideas and empirical evidences on the relation between IDs and markets of technology. The fact that the ID model of innovation is mostly based on incremental paths of innovation without formal R&D activities, it is quite a general feature of IDs, above all in the Italian case (Belussi and Gottardi, 2000).

According to micro-macro evolutionary models of technological change in agent-based industrial systems (our references are: Ballot and Taymaz 1999; Carlsson, Eliasson and Taymaz 1997), we have modelled a cycle of technological learning of ID firms based on technology absorption, organisational learning, and technology saturation phases. Firms need to accomplish such cycle in order to improve their economic performance. Learning is modelled as a combination of production factors with an initial state (0, 0, 0, 0) and a fixed best practice level (1, 1, 1, 1). There are four production factors, such as capital, labour, human skills, and internal information and communication architectures. Firms need simply to experimentally discover the best practice level, within all the technological regimes (T1, 2, 3), that is to say the best way to combine the aforementioned four factors.

Shortly, technological learning is conceived as a process in which firms adapt their organisational assets to technological standard features, investing resources into internal organisational change. The evolution of the combination of factors represents the evolution of the firm organisational asset. It should be viewed as a sequential set of micro-organisational changes, such as investments in formation of professional capabilities, re-engineering of production processes, updating of communication and information tools, that firms need to do in order to adapt to technology and market evolutionary options. Firms do not know all the possible combinations of production factors, and they do not have a perfect vision of technological features and possibilities shaped by the environment. Firms try simply to experiment changes in their combination of factors and to adapt their organisational assets to technological features of the market. In some sense, it is a matter of what Cohen and Levinthal (1990) call the "absorptive capacity".

As it is shown in Squazzoni and Boero (2002), performance at individual level depends on techno-organisational features of firms, while at chain level, it is affected by collective features of the chain as a whole, that is, to say, both by the technological level of interacting firms and by their degree of technological compatibility. Higher is that degree, faster is the production process, less problematic are the operations of assemblage of the final product, and bigger is the collective profit emerging. This element is what in our code is called the "time compression" advantage. Shortly, we assume that technologically compatible interacting firms have a common standard of communication that improves the quality of collective production processes, making production chains more able to respond quickly to market requests (i.e., on relations between market volatility and adaptation of value-chains, see: Steinle, Schiele 2002).

As we said before, firms are embedded into a topology of proximity relations, both in a spatial and organisational sense. Proximity relations are sources of information and mutual monitoring among firms.

To regulate proximity relations, we introduced a "neighbourhood set" for each agent. The spatial proximity function is implemented using arrays which regulate all the mutual positions of firms, inside their classes. For each firm, the neighbourhood is composed by two firms that are located at the right and the left. We assume that a firm can always monitor performance values of its neighbouring firms, looking at their technological level and their combination of technical factors. We assume that, if a firm discovers that the performance of a specific neighbour is higher than its own, and that there are differences into their respective technological features, then it can adjust its own combination, imitating the technological paradigm or pieces of the organisational assets from the neighbourhood. Clearly, neighbourhood relations are mutual and bi-directional and they imply costs regulated by the "InfoMatrix" (see Figure 1).

Proximity relations give rise to a dynamic and flexible infrastructure of information flow. In fact, they are the context within which firms move. The relevant information, concerning technology and market environment, comes from final firms facing the market and spreads along the system, both by means of direct inter-firm relations (organisational chains) and spatial relations (spatial neighbourhood).

Taking a look to the agent-level, we assume that firms are characterised by a resource level, a technological level, and a performance level. We assume that at the beginning, firms have the same level of resources to invest. By monitoring the aforementioned levels, and by using sources of information coming from their organisational or spatial relations, firms make choices of technological investment trying to improve their economic performance. We assume some possible actions for firms:

- a **radical innovation by exploration**, that is to say an attempt to change the technological regime used, taking a very risky investment (jump from T1 to T2 and from T2 to T3);
- an **incremental innovation by internal exploitation**, that is to say a phase of investments on the internal organisational, at a given technology *T,* where firms try to improve the technology changing their combination of production factors;
- an **imitation by external exploitation**, that is to say a technological or organisational imitation based on relevant information coming from the neighbourhood set mentioned above.

According to the literature in the field of evolutionary economics, technological change and organisational learning (Dosi 2000; March 1991), we introduced alternative behaviour options as different strategies and different learning tools for firms: given their information context, firms can choose to open their space of exploration towards technological environment (checking the availability of new technologies), or to improve their organisational assets, both looking inside themselves (are incremental changes and better ways to internally organise production possible factors?), and exploiting information coming from their neighbourhood (is it better to follow learning steps undertaken by other firms?). Clearly, these are options continuously available for firms action, but preferences depend on the nature of the dynamic context of interaction which surrounds firms (information) and on the adaptation imperatives coming from the market (technology).

In order to regulate the costs for all these alternative actions, we have introduced three parameters matrices: “InfoMatrix”, “TechMatrix” and “ChangeMatrix” (see Figure 1, 2, and 3).

Figure 1 shows what we call the “**TechMatrix**”. Here is presented data on the relation between technology and learning. The evolution of technology (T1, T2, and T3) is characterised by increasing costs and increasing values of performance, over time. Inside the technological regimes, there are five steps of learning (from 0000 to 1111). The column A of Figure 1 shows the increasing cost of production, for all the possible learning steps undertaken by firms. The column B shows the achievable levels of production performance of firms. The third one (column C) shows the decreasing cost generated by the use of the same combination for more than one cycle. Such saving is modelled according to the idea of learning by doing and using (Arthur, 1994).

Figure 2 shows the “**ChangeMatrix**”. Here is presented the structure of costs that firms need to sustain in order to implement a new technology (first line), to improve their internal assets (second line), and to establish a cooperative production relationship with firms belonging to the external industry system (partnership externalisation, third line). For instance, costs presented in the first line can be conceived as costs to purchase new production machines, while the ones on the second line can be interpreted as costs to adapt organisational assets to the technology, like training activities of human capital needed to sustain technological processes of innovation inside firms, and finally about the third line, as costs to define cooperation, contractual partnerships, monitoring activities, communication and information exchanges, with firms outside ID. As in the case of “TechMatrix”, costs increase gradually over time, with the growth of complexity of technological regime.

Figure 3 shows what we call the “**InfoMatrix**”. It contains costs that final and sub firms must pay in order to achieve different types of information. Information concerns technological and organizational assets of neighbouring firms, technological exploration inside the environment and activities related to partnership selection. The first two lines show the cost of imitation concerning technological and organisational assets implemented by two neighbouring firms. It is the cost of the acquisition of knowledge about techno-organisational features of neighbouring firms. The data in line number three and four represents the costs concerning the information about a new available technology, and the implementation of a new combination of organisational factors. As in the case of foregoing matrices, costs increase gradually over time, with the growth of complexity of the technological regime.

The last two lines show cost of information which final firms must pay in order to find the best sub contracted firms available inside (fifth line) and outside (sixth line) ID, for organising a production chain. Costs are assumed to be fixed over time[3].

[3] Check the appendix for a detailed analysis of the parameters structure and initialisation.

Figure 1: Matrix of technological and technical production costs

	T1			T2			T3		
Technique	A	B	C	A	B	C	A	B	C
0000	5	9	0.01	6.655	13.68788	0.01	8.857805	20.81755	0.01
0001	5.5	10.35	0.01	7.3205	15.74106	0.01	9.743586	23.94018	0.01
0011	6.05	11.9025	0.01	8.05255	18.10221	0.01	10.71794	27.53121	0.01
0111	6.655	13.68788	0.01	8.857805	20.81755	0.01	11.78974	31.66089	0.01
1111	7.3205	15.74106	0.01	9.743586	23.94018	0.01	12.96871	36.41002	0.01

Figure 2: Matrix of costs of technological and technical change

	T1	T2	T3
Technological Change		200	400
Technical Change	50	100	200

Figure 3: Information and research costs

	T1	T2	T3
Technological Assets Imitation	40	70	
Organisational Assets Imitation	30	20	10
Technological Assets Innovation	70	150	
Organisational Assets Innovation	60	40	20
Best sub firm on Technology	5	5	5
Best sub firm on Performance	20	20	20

4. Simulation Settings *H1* and *H2* : "Market-like" vs. "Partnership Structure"

As it is shown also in Squazzoni and Boero (2002), first simulation settings concern a comparison between the two behavioural styles mentioned above. The behavioural style of market-like ID firms is driven by economic inputs. It is a matter of a set of myopic economic criteria that affects mechanisms through which partnership materialises and production chains are managed. Final firms follow a simple criterion, choosing the best team of subcontracted firms available during every production cycle, basing the choice on actual economic data, with a short run perspective. ID final firms behave simply trying to optimise partnership and interaction context. After they have received a request of product by the market, they move inside the system, searching for a team of subcontracted firms to organise a production chain. Such search for partners works by means of a classification of possible partners within the system, according to their economic performance outcomes. Time horizons of interaction are bounded to a one-shot interaction. At the start of the production cycle, ID firms memory is erased. From another perspective, in this case inter-firm relations within ID conform to classic ideas about subcontracting relations, as though they were regulated by what Cavestro and Duriex (2000) call “internal market of individual contracts”.

Instead, the behavioural style of partnership ID firms is driven by criteria of commitment and cooperation and by the search for an effective management of long-lasting partnership relations. Thus, time horizons of interaction are enlarged. Final firms keep in their bounded memory the outcome of previous interactions and they are prone to identify and commit their foregoing partners. Criteria of selection and management of production chains, rather than being set out by economic features, are determined by technological cooperation. Operations are as follows: if a production chain produces a value of time compression (technological compatibility) which is the same as, or higher than the one of the foregoing cycle, then final firms do not search for a new team of subcontracted firms. In order to increase the technological compatibility among firms interacting along the chain, final firms can allocate the 40% of the final profit emerging by the chain to their interacting subcontracted firms, transforming some of their profit into back-propagating distributed resources. Such resources become incentives for firms to cooperate into recurring interactions along the chains, and tools for creating commitment-based stable relations of partnership, allowing unified path in technological adoption. In short, final firms compute functions of collective intelligence, becoming a kind of chain-based technology policy makers (Cavestro W., Durieux C. 2000).

In order to test *H1* and *H2*, we run ID prototype comparing the outcome of the two aforementioned ID simulation settings. What kind of relation can there be between metrics of proximity and styles of behaviour? Do behavioural styles affect the function of proximity relations as tools of technological learning?

Summarising simulation results, we can stress that the market-like ID shows low economic performance of firms, strong selection caused by the market, great instability of inter-firm relations, high costs of coordination, high volatility and instability of aggregated profits emerging from chains, and critical effects of technological shocks on the ID as a whole (see Figure 4 and 6). Concerning proximity relations and looking at an agent-based level, it is possible to stress that the complex architecture of proximity metrics implies a high complexity of sources of information surrounding firms. Firms need to process information coming both from organisational relations, along production chains, and from spatial neighbourhood relations, trying to transform such information into tools for defining coherent technological behaviours, articulating phases of technological exploration and exploitation. If the structure of inter-firm relations becomes highly unstable over time, firms face a continuous information overloading that affects the transformation of proximity-based information into tools of useful learning. Looking at investment trends of firms, it is possible to outline that the market-like ID implies high schizophrenia in firms behaviour. This is due to the weakness and volatility of inter-organisational links. What matters is that, because of economic style of behaviour and instability of production partnership, ID firms go through a conflict of proximity metrics, with incapacity of exploiting the information flow in a coherent way and carrying out the aforementioned sequential phase of technological learning (absorption, learning, saturation).

This fact is even more evident if one compares market-like ID with partnership structure ID outcomes. The latter ID shows higher economic performance of firms, reduction of the strong selection caused by the market evolution, emergence of dynamics of lock-in and lock-out inside the chain, that fit well with inter-firm coordination between technological phases of exploration and exploitation, higher capacity for firms to calculate and to follow more rationally the sequential phases of learning, and reduction of the impact of technological shocks. Here, spatial proximity relations are enacted during phase of exploration and lock-out of organisational relations, as sources of mutual monitoring among firms belonging to the class. When firms need to explore, they open completely their information sources and possibilities, while when firms need to exploit, they close information sources to the chain, following collective learning phase within inter-organisational relations. Here, the stability of production chains becomes a tool of coordinated learning among firms. The information overloading affecting firms in the market-like ID is reduced by the stability of inter-organisational relations (see Figure 5).

Summarising the outcome of first simulation settings, we can draw some conclusions on *H1* and *H2*. Proximity-based information is fundamental for learning and coordination of ID firms. Different proximity metrics have different learning functions. In fact, spatial proximity matters for circulation of relevant technological information among firms in phase of technological innovation, while organisational proximity matters in defining partnership structures able to make technological learning a collective and well sustained feature of IDs, namely in phase of exploitation and inter-firm learning coordination. Without the emergence of strong organisational relations able to coordinate interacting firms, spatial proximity runs the risk of becoming a source of lack of inter-organisational coordination and loss of economies, both from the point of view of individual and collective learning paths. But, what matters in transforming proximity relations into learning tools is the style of behaviour of ID firms. In a context of interdependence, such as that of IDs, what matters for strategic ID firms is being able to define long term partnerships with other complementary firms that is based on commitment, cooperation, circulation of information, mutual coordination. This is possible only if firms behave far from pure market style (short-run optimising economic agent), exchanging optimisation in a short period for adaptation in the long term.

Figure 4: Final firms matching market requests over time. Comparison between market-like (on the left) and partnership structure ID (on the right). The two phases of technological discontinuity are fixed respectively around 500 and 1000 simulation cycles. At the end of simulation cycles, we have 20% of surviving firms in the first simulation setting, while 56% in the second one.

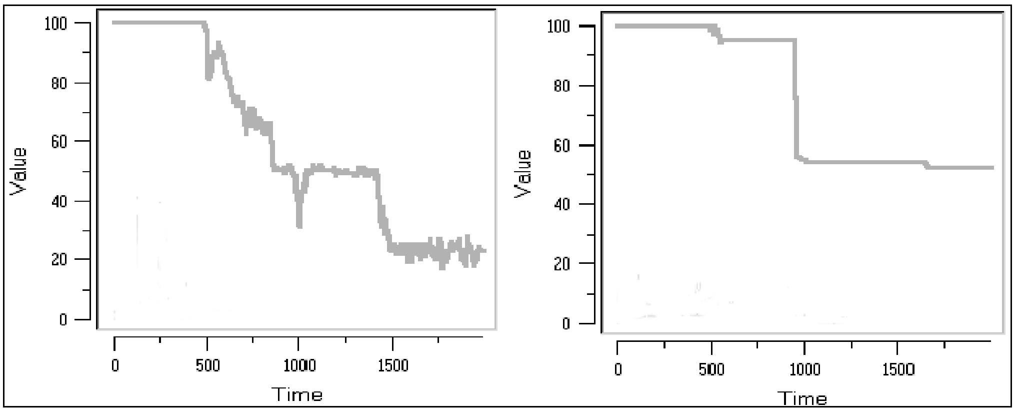


Figure 5: Size and dynamic of spatial proximity-based imitation strategies before the first technological shock (transition from T1 to T2). Comparison between market-like (on the left) and partnership structure ID (on the right). In the case of partnership structure ID, the influence of spatial proximity relations as information sources for firms is reduced, while the stabilisation of organisational proximity relations grows up.

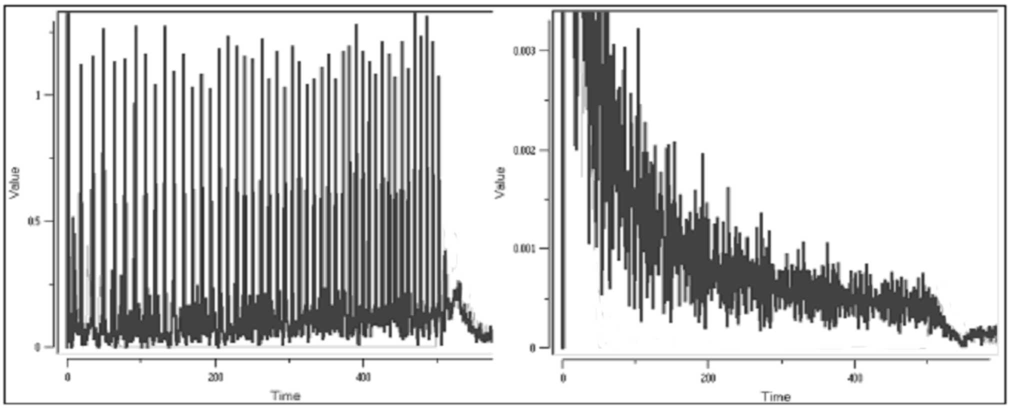
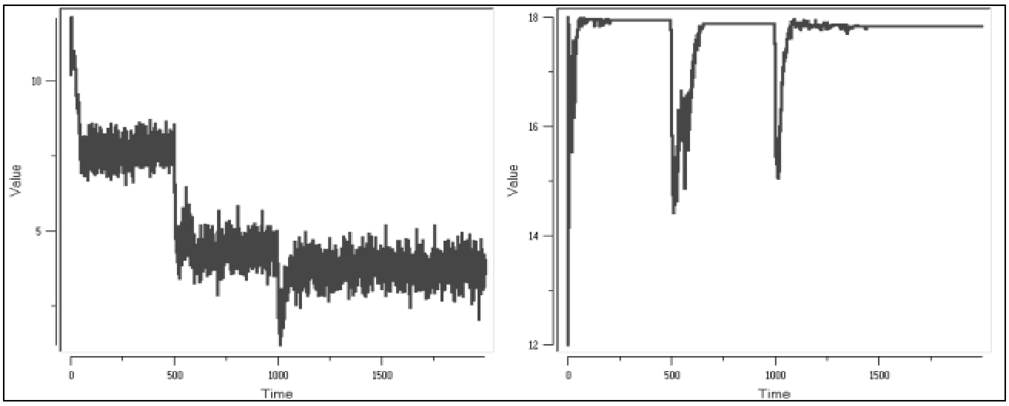


Figure 6: Dynamics of the aggregate profit emerging by production chains, measured in terms of "time compression value" (it measures the degree of technological convergence and compatibility among firms interacting along the same production chains). Comparison between market-like (on the left) and partnership structure ID (on the right). It is possible to observe the higher volatility, instability and lower levels of collective profits in the market-like in respect to partnership structure ID.



5. Simulation Setting *H3*: Partnership Externalisation and Supporting Institutions

Second simulation settings concern the introduction of the possibility for ID final firms to externalise parts of subcontracting relations to the external industry system. This is what ID scholars call "production de-localisation" and this is the main subject of several recent debates on IDs. Does de-localisation mean a crisis of IDs as a local closed system, or is it a sign of maturity of IDs facing globalised, international, and ICT based markets? These are some questions which have been recently circulating among ID scholars (Cossentino, Pyke and Sengenberger 1996; Whitford 2001). Some scholars focus on the advantage of spatial proximity relations, which is related to reduction of coordination costs and lowering of transaction costs within IDs. The presence of strong informal links among ID agents allows continuous possibilities of mutual monitoring and control among agents that are embedded into the same social and geographical space (Cooke and Morgan 1998; Dei Ottati 1994; You and Wilkinson 1994). Some others focus on the advantage of externalisation, which is mostly related to the recovery of de-localisation costs allowed by ICT, or to possibilities of economies of variety that are related to the interaction with firms that are external to ID.

Therefore, our first aim is to test externalisation in IDs based on the partnership structure, as defined above, trying to understand if it has a positive or negative impact on the ID as a whole.

On one hand, staying inside ID, firms have lower costs of coordination, but with the possibility of interacting with partners not well endowed from the technological point of view. On the other hand, trough subcontracting external firms, firms have higher costs of coordination, but the possibility of interacting with firms endowed with optimal technological features. In short, our first aim is to compare the advantage of spatial and organisational proximity inside ID with the advantage of a search for partnership optimisation at the edge of the external industry system.

To do this, we introduce in the ID prototype a parallel market of firms, representing an external industry system. Firms, both internal and external to ID, operate into the same technological environment and market, but external firms move inside a perfect market, where information flow circulates completely without asymmetry between final and subcontracting firms, and they behave trying continuously to optimise the quality of their products. They move on the best technological trajectories.

External partners are conceived as resources available to ID firms, which, when exploiting such resources, pay costs of coordination shown in "InfoMatrix" and "ChangeMatrix" (see Figure 2 and 3). If ID firms choose to externalise their production chains, the sources of cost are related to research, selection, and coordination. The ones regarding external coordination are higher than internal costs of coordination, as it is shown in the last line of the "InfoMatrix" (figure 2). We assume that the coordination between the ID and external firms implies costs of distance (exploration in the external industry system), and needs to explicit the tacit knowledge embodied in the ID firm in order to define an effective transaction. In our model, these costs increase with the growth of technology and the consequent market evolution. Moreover, we assume the absence of explicit or implicit control mechanisms within the ID which punish the treason of an externalising firm.

The choice of externalisation for ID final firms depends on the fact that a chain produces a value of time compression that is lower than the one of the foregoing cycle. Then final firms start to seek new technologically compatible partners with an high economic performance within the ID environment; if this option does not produce interesting outcomes, then final firms start to explore external industry system, or parallel market system, i.e. looking for external partners. A final assumption is the fact that the availability of external partners is bounded: as there are, in the model, 100 firms inside the ID for each productive specialisation, there are 100 external firms for each production segment.

The other aim of the second simulation setting is to test the role of a supporting institution which could be able to monitor the industry system and to set up an effective networking among firms inside and outside the ID. The function of different kinds of supporting institutions in IDs, such as consortia, service centres, associations, and so on, with both outside-in and inside-out functions, and conceived as institutionalised forms of "joint actions" (Schmitz 1999), is well described in ID and clusters literature (Amin and Thrift 1994; Bianchi and Giordani 1993; Buratti, Penco 2001; Cooke and Morgan 1998; Glasmeier 1999; Hassink 1996; Helmsing 2001; Lombardi 2003b; Lorenzen 2001), as well as the role of institutional re-enforcement upon firms experimental strategies has been described in detail in evolutionary economics literature (Dosi 2000; Nelson 1998).

Our aim is to test *H3* giving an example of a relevant institutional engineering option. The external industry environment could be viewed both as a geographically localised industry and a specialised market. Our aim is to understand if partnership externalisation can have positive effects on ID firms adaptation, just because it is supported by scaffolding institutions able to monitor the evolution of the industry system (or a specific external industrial local area), to give relevant technological information to ID firms, and to partially re-enforce partnership contracts from an outside-in perspective.

We introduce a supporting institution such as a consortium among ID firms. We assume that, automatically since the first cycle of simulation, 50% of ID final firms are institutional members. The cost of institutional services is distributed over institutional insiders during each cycle of simulation. Firms keep on being institutional insiders, until they have resources to pay institutional actions. Institutional cost is calculated with respect to "Info" and "Change Matrix", as a cost of functioning of institutional actions divided for number of insiders, and it grows over time with the evolution of technology.

The institution aims to search for external partners when final firms need them. It is able to continuously monitor the external industry system, to rank both external and ID potential partners according to technological needs of insiders. If final firms choose to externalise their production chains, the supporting institution is able to identify an useful team of subcontracted firms and to support inter-firm partnership for ten production cycles. After these ten cycles, final firms are free to carry on with external partners or to seek for new partners. In other words, final firms try to choose the right action to improve the degree of technological fitness of their interacting partners and of the chain as a whole.

To observe emerging dynamics of second simulation settings, we use some comparative indicators as the level of surviving firms over time, the level of performance of final firms over time, the level of stability and instability of production chains over time, the level of "time compression" within production chains (it measures the degree of technological compatibility among interacting firms and the level of "aggregated profit" emerging from chains), and the number of production chains which involve "internal" or "external" firms.

As we said before, the evolutionary environment of the ID is marked by an alternation of phases of technological continuity and discontinuity. These are phases during which it is possible to observe the adaptive capacity of ID firms and the role of different proximity relations as tools of learning, or as processes with a lock-in effect. The first comparison is between partnership structure ID and the ID with externalised partnership. As we stressed in the previous paragraph, the partnership ID shows dynamics in which cycles of lock-in and lock-out of organisational relations adapt to phases of individual and collective exploitation and exploration activities, in which reduction of information variety during technology exploitation phases allows to avoid the schizophrenia trap which characterises the market-like ID and to coordinate collective learning within production chains. Moreover it shows that inter-organisational lock-in is broken when leading firms face a phase of radical technological innovation, during which they start to aggregate another team of sub contracted firms able to follow the required radical jump, while innovation implies chain lock-out and the search for new coordination assets and critical effects of technological discontinuities are absorbed by means of the opening of agent-based exploration and the capacity of final firms to configure new inter-organisational assets. Finally spatial proximity works above all during phases of redesign of inter-organisational assets, and stability of organisational relations allows high-level collective economic outcomes (with tendencies towards high final profit emerging by chains).

Comparing outcomes with the ID with externalised partnership it is possible to observe that during the first phase of technology discontinuity (after 500 cycles), almost 30% final firms try to externalise partnership. For the next 100 cycles, such an option, which causes an instability of inter-ID firm relations and an intense phase of market selection (see Figure 7), is quite totally shrank. Only 9 final firms keep on externalising. During the second phase of technology discontinuity (after 1,000 cycles), the market selection strikes even the externalised chains, causing a kind of return to the fold, even for partially externalised chains, and strengthening again the ID.

Shortly, the comparison shows that the performance of the ID is not improved by the externalisation option, not causing any advantage from the point of view of technological learning and market adaptation of ID firms. Even if final outcomes seem to be similar at the aggregation level, externalisation seems to cause a penetration of uncertainty that undermines the stability of ID partnership structure, while it does not promote a weakening of the organisational stiffness of ID. Observing figures 8, 9 and 10, it is possible to outline that collective efficiency of organisational assets matters even if individual outcomes of final firms tends to grow up by means of externalisation strategies. As in the foregoing simulation settings, where the comparison was between market-like and partnership structure ID, the economic individual imperatives leading final firms externalisation strategies seem to conflict with inter-organisational mechanisms typical of ID. The performance of final firms grows with externalisation strategies, but advantages related to the stability of partnership assets, as *loci* of coordinated learning, are lost.

Figure 7: Final firms matching market requests over time in the case of the ID with externalised partnership (to compare with outcomes of partnership structure ID in the figure 4). "A" is the number of surviving ID final firms, while "B" is the total number of surviving final firms, both of ID and industry system.

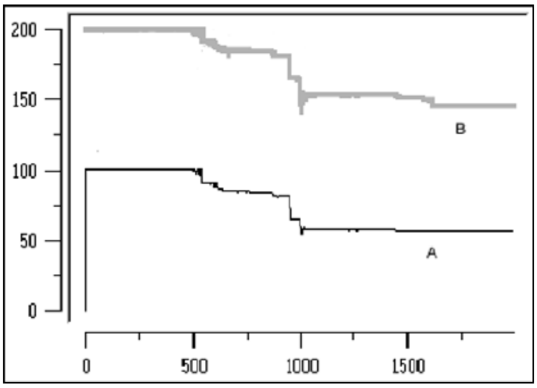


Figure 8: Dynamics of stability and instability of organisational relations over time. On the left, outcome of the partnership structure ID, while on the right, outcome of the ID with externalised partnership.

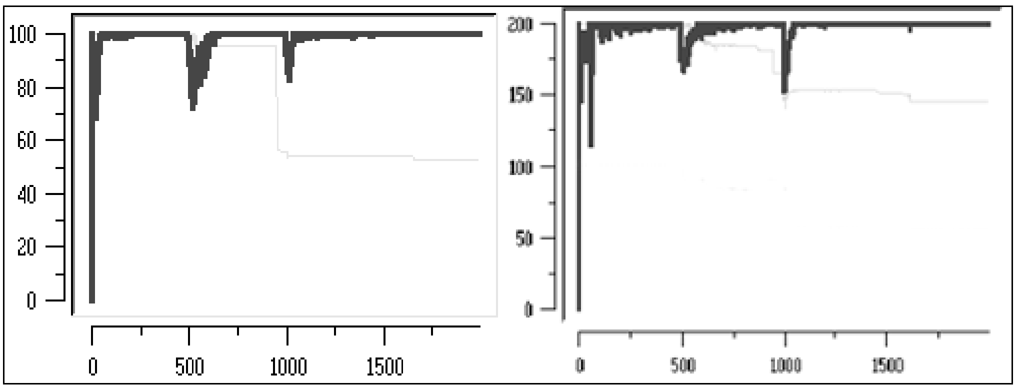


Figure 9: Level of performance of final firms over time. On the left, outcome of partnership structure ID, while on the right, outcome of the ID with externalised partnership. It is possible to observe that, during

phases of technological discontinuity, final firms performance grows to a great extent when they re-organise inter-organisational assets staying inside ID.

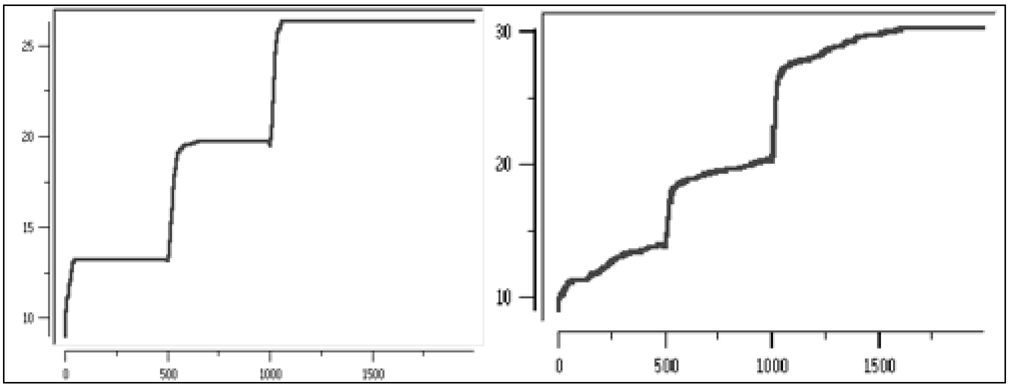


Figure 10: Level of "time compression" of production chains over time in the case of ID with externalised partnership (to compare with partnership structure ID, figure 6, on the left part). During phase of technological discontinuity, collective outcomes emerging from production chains decrease with the growth of externalisation.

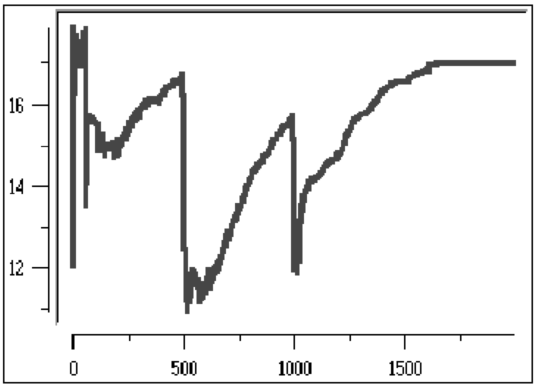
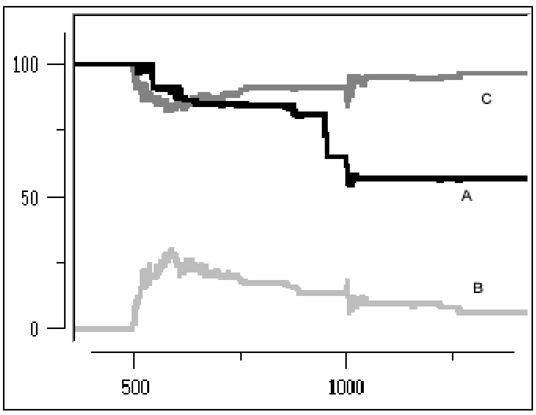


Figure 11: Interwoven indicators: "A" is the level of ID final firms staying on market over time; "B" is the number of final firms choosing externalisation; "C" is the number of chains composed only by ID firms. It is possible to observe that during the phase of technological discontinuity (around 500 cycle), ID faces a phase of instability characterised by the emergence of externalisation and a crisis of market outcomes. Such phase is absorbed when firms come back to ID.



Finally, the first outcome of the second simulation setting has to be compared with the one of the ID with a supporting institution. *H3* should be confirmed if the effect of supporting institution can solve problems shown by ID with externalised partnership. Is externalisation bad at all? Or does externalisation hide problems of coordination, cooperation and definition of partnership that a supporting institution could solve?

Looking at the outcomes of the institutional setting, it is possible to observe that the effect of institution has a positive impact on ID firms performance (see Figure 12), strengthening both in phases of technological continuity and discontinuity, and, above all, during the critical phases of ID evolution. Moreover, it has a positive impact on technological outcomes of production partnership (see Figure 13), with values of "time compression" above the foregoing average, and on market adaptation, too (see Figure 14). In fact, technology and market performance of ID firms are more stable than in the case of the ID with externalised partnership, more continuous, and less affected by evolutionary challenges of the technological environment. Finally, institutional setting shows that 95% of ID firms survive until the end of simulation.

In conclusion, it is possible to stress that *H3* is confirmed: externalisation is not bad at all, but it needs to be institutionally supported with specialised focused services, such as those described here, in order to become an evolutionary advantage for ID firms. Individual agent activities need to be supported by institutions able to identify practical solutions to collective problems and to give fundamental information infrastructures, but leaving firms free to pursue their experimental activities.

Figure 12: Level of performance of ID final firms over time in ID with supporting institutions.

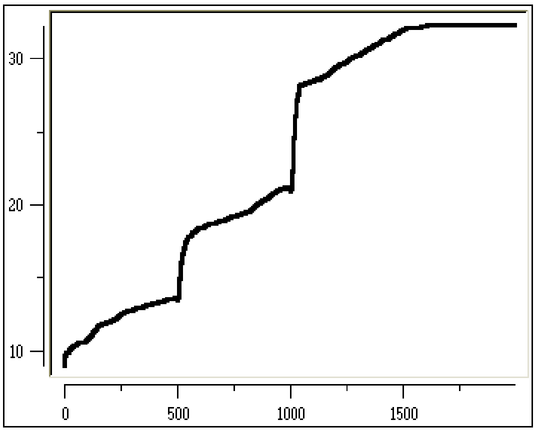


Figure 13: Level of "time compression" of production chains over time in the case of ID with supporting institutions (to compare with partnership structure ID, figure 10).

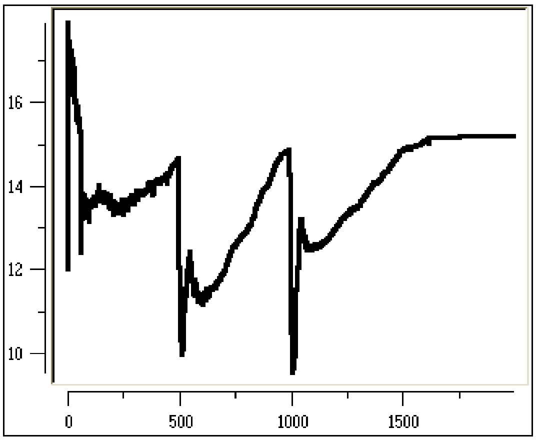
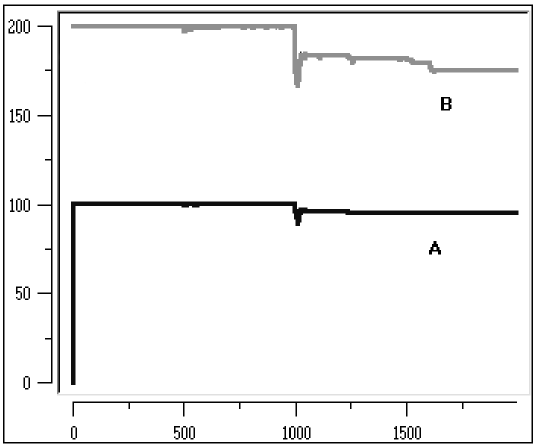


Figure 14: Final firms matching market requests over time in the case of ID with supporting institution (to compare with outcomes of ID with externalised partnership in the figure 7). "A" is the number of surviving ID final firms, while "B" is the total number of surviving final firms, both of ID and industry system.



6. Conclusion: Behavioural Styles, Proximities and Institutions

The hypotheses suggested at the beginning of the paper have been tested by means of a comparison among different simulation settings. The outcome shows that proximity relations really matter as informal information infrastructures able to sustain agents learning paths. But, a close look both to their different and overlapping metrics and to the role of different behavioural style of agents, allows some interesting theoretical intuitions. As several scholars on industrial clusters have rightly emphasised (Torre and Gilly 2000; Gilly and Wallet 2001), proximity metrics and dynamics play an important function of carrier for firms learning processes, but they have different, even conflicting, features (see: Caniêls 2000; Caniêls and Romijng 2001). Thanks to an ABMs perspective, we have tried to avoid the trap picked out by Oerlemans, Meuss, Boeckema (2001), Staber (2001a, 2001b), Trigilia (2001) and Uzzi (1997) among others, that is to assume agents behaviour as a black box automatically and naturally shaped by properties of spatial/social network that surrounds agents. Rather, we have tried to show that proximity relations are produced by behavioural styles at micro level. Our simulations show that spatial and organisational proximity metrics should be conceived as overlapping and mutually deforming information resources that need to be enacted and controlled by firms, according to their technological adaptation challenges and to a right sequence of learning by exploration and exploitation phases.

Moreover, first simulation settings show that successful ID performance depends on cooperative styles of action. According to the idea that innovation in a distributed system is a complex phenomenon, the capacity of innovative firms to design an effective inter-organisational asset is very important. A cooperative style of behaviour is needed by final firms to enact a context of commitment among firms, and to exploit inter-organisational ties, too.

About simulation settings on externalised partnership ID, with the eventual presence of supporting institutions, what mainly emerges is that institutions can play a fundamental role to sustain firms needs, above all in strategic situations such as externalisation. Focusing on well restricted collective goals, such as in our case, monitoring and networking between the ID and the external industry system, institutions can allow ID firms to gain environmental exploration advantages, absorbing risks of uncertainty and avoiding schizophrenic agents strategies, as well as the loss of robustness of the ID as a whole.

Aknowledgements

Riccardo Boero would like to gratefully acknowledge the "Progetto Lagrange - Fondazione CRT" for financial support.

References

Albino, V., Garavelli, A.C., Schiuma, G. (1999) Knowledge Transfer and Inter-Firm Relationships in Industrial Districts: The Role of the Leader Firms. *Technovation*, 19, 53--63.

Amin, A. and Thrift, N. (Eds.) (1994). *Globalization, Institutions and Regional Development in Europe*. New York: Oxford University Press.

Arthur, W.B. (1994). *Increasing Returns and Path Dependence in the Economy*. Michigan: University of Michigan Press.

Arthur, W.B., Durlauf, S.N., Lane, D. (Eds.) (1997). *The Economy as an Evolving Complex System II*. Santa Fe Institute Studies in the Sciences of Complexity, Massachussets: Addison- Wesley Publishing Company.

Auyang, S.Y. (1998). *Foundations of Complex- System Theories in Economics, Evolutionary Biology and Statistical Physics*. Cambridge: Cambridge University Press.

Ballot, G. and Taymaz, E. (1999). Technological Change, Learning and Macro-Economic Coordination: An Evolutionary Model. *Journal of Artificial Societies and Social Simulation*, 2, 2, *http://www.soc.surrey.ac.uk/JASSS/2/2/3.html*.

Becattini, G. (1990). The Marshallian Industrial District as a Socio-economic Notion, in F. Pyke, G. Becattini, and W. Sengenberger (Eds.), *Industrial Districts and Inter-Firm Cooperation in Italy*. Geneva: International Institute of Labour Studies.

Bellandi, M. (2002). Italian Industrial Districts: An Industrial Economics Interpretation. *European Planning Studies*, 10, 4, 425--437.

Belussi, F. and Gottardi, G. (Eds.) (2000). *Evolutionary Patterns of Local Industrial Systems. Towards a Cognitive Approach to the Industrial District*. Aldershot Brookfield Singapore Sydney: Ashgate.

Bianchi, P. and Giordani, M.G. (1993). Innovation Policy at the Local Level and at the National Level. The Case of Emilia-Romagna. *European Planning Studies*, Vol. 1, No.1, 24--41.

Boari, C. and Lipparini, A. (1999). Networks within Industrial Districts: Organizing Knowledge Creation and Transfer by Means of Moderate Hierarchies. *Journal of Management and Governance*, 3, 339--360.

Brusco, S. (1982). The Emilian Model: Productive Decentralisation and Social Integration. *Cambridge Journal of Economics*, Vol. 6, 167--184.

Buratti, N., Penco, L. (2001). Assisted Technology Transfer to SMEs: Lessons from an Exemplary Case. *Technovation*, 21, 35--43.

Caniêls, M. (2000). *Knowledge Spillovers and Economic Growth*. Cheltenham: Edward Elgar.

Caniêls, M. and Romijn, H. (2001). Small-Industry Clusters, Accumulation of Technological Capabilities, and Development; A Conceptual Framework. *Eindhoven Centre of Innovation Studies, ECIS Working Paper 01-05*.

Carbonara, N., Giannoccaro, I., Pontrandolfo, P. (2001). Supply-Chains within Industrial Districts: A Theoretical Framework. *International Journal of Production Economics*, 1--18.

Carlsson, B., Eliasson, G., and Taymaz, E. (1997). Micro-Macro Simulation of Technological Systems: Economic Effects of Spillovers. In B. Carlsson (ed.), *Technological Systems and Industrial Dynamics*. Boston: Kluwer Academic Publishers.

Cavestro, W., Durieux, C. (2000). Firmes, réseaux et apprentissage. *Economie et Sociétés*, Séries F, 37, 9, 87--100.

Cohen, W., Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35, 128--152.

Conte, R., Hegselmann, R. and Terna, P. (1997). Social Simulation- A New Disciplinary Synthesis. In (Eds.), *Simulating Social Phenomena*. Berlin: Springer-Verlag.

Cooke, P. (2002). *Knowledge Economies. Clusters, Learning and Cooperative Advantage*. London: Routledge.

Cooke, P. and Morgan, K. (1998). *The Associational Economy. Firms, Regions and Innovation*. New York: Oxford University Press.

Corò, G. and Grandinetti, R. (2001). Industrial Districts Responses to the Network Economy: Vertical Integration versus Pluralist Global Exploration. *Human Systems Management*, 3.

Cossentino, C., Pyke, F. and Sengenberger, W. (Eds.) (1996). *Local and Regional Response to Global Pressure: The Case of Italy and its Industrial Districts*. Geneva: International Institute for Labour Studies.

Dei Ottati, G. (1994). Co-operation and Competition in the Industrial Districts as an Organizational Model. *European Planning Studies*, No.4.

Dosi, G. (2000). *Innovation, Organization and Economic Dynamics. Selected Essays*. Cheltelham, UK, Northampton, MA, USA: Edgar Elgar.

Epstein, J.M., Axtell, R. (1996). *Growing Artificial Societies. Social Science from the Bottom-Up*. Cambridge: MIT Press.

Gilbert, N. and Terna, P. (2000). How to Build and Use Agent-Based Models in Social Sciences. *Mind & Society*, I, 1, 57--72.

Gilly, J.-P. and Wallet, F. (2001). Forms of Proximity, Local Governance and the Dynamics of Local Economic Spaces: The Case of Industrial Conversion Processes. *International Journal of Urban and Regional Research*, vol. 25, 3, 553--570.

Glasmeier, A.K. (1999). Territory-Based Regional Development Policy and Planning in a Learning Economy: The Case of "Real Service Centers" in Industrial Districts. *European Urban and Regional Studies*, Vol. 6, No. 1, 73--84.

Hassink, R. (1996). Technology Transfer Agencies and Regional Economic Development. *European Planning Studies*, Vol. 4, Issue 2.

Helmsing, A.H.J. (2001). Externalities, Learning and Governance: New Perspectives on Local Economic Development. *Development and Change*, Vol. 32, 277--308.

Hofstadter, D.R. (1979). *Gödel, Escher, Bach: An Eternal Golden Braid*. New York: Basic Books.

Lane, D. (1993). Artificial Worlds and Economics, Part II. *Journal of Evolutionary Economics,* 3, 3, 161--174.

Lane, D. (2002). Complexity and Local Interactions: Towards a Theory of Industrial Districts. In Curzio Quadrio, A., Fortis, M. (Eds.), *Complexity and Industrial Clusters*. Berlin: Springer Verlag.

Lazerson, M.H. and Lorenzoni, G. (1999a). The Firms that Feed Industrial Districts: A Return to the Italian Source. *Industrial and Corporate Change*, vol. 8, 2.

Lazerson, M.H. and Lorenzoni, G. (1999b). Resisting Organizational Inertia in Industrial Districts. *Journal of Management and Governance*, 3, 361--374.

Lissoni, F. (2001) Knowledge Codification and the Geography of Innovation: The Case of Brescia Mechanical Cluster. *Research Policy*, 30.

Lombardi, M. (2003a). Cognitive Models, Efficiency, and Discontinuities in the Evolution of Local Production Systems. In F. Belussi, G. Gottardi, and E. Rullani (Eds.), *Knowledge Creation, Collective Learning and Variety of Institutional Arrangements*, Kluwer, Dordrecht:109-138.

Lombardi, M. (2003b). The Evolution of Local Production Systems: The Emergence of "Invisible Mind" and the Evolutionary Pressures Towards More Visible "Minds". *Research Policy*, 32, 8, 1443--1462.

Lorenzen, M. (2001). Localized Learning and Policy: Academic Advice on Enhancing Regional Competitiveness through Learning. *European Planning Studies*, Vol. 9, No. 2.

March, J.G. (1991). Exploration and Exploitation in Organizational Learning. *Organization Science*, 2, 1, 71--87.

Molina-Morales, F.X. and Martinez-Fernandez, M.T. (2003). The Impact of Industrial District Affiliation on Firm Value Creation. *European Planning Studies*, 11, 2, 155--170.

Nelson, R.R. (1998). The Co-evolution of Technology, Industrial Structure, and Supporting Institutions. In G. Dosi, D.J. Teece, and J. Chytry (Eds.), *Technology, Organization, and Competitiveness. Perspectives on Industrial and Corporate Change*. New York: Oxford University Press.

Oerlemans, L.A.G., Meuss, M.T.H. and Boekema, F.W.M. (2001). Innovation, Organizational and Spatial Embeddedness: An Explanation of Determinants and Effects. *Eindhoven Center of Innovation Studies, Working Paper 01-03*.

Pilotti, L. (2000). Networking, Strategic Positioning and Creative Knowledge in Industrial Districts. *Human System Management*, 19, 121--133.

Porter, M. (1998). Clusters and Competition, in *On Competition*, Cambridge: Harvard Business Review Press.

Rullani, E. (2003). The Industrial District (ID) as a Cognitive System, in F. Belussi, G. Gottardi and E. Rullani (Eds.), *Knowledge Creation, Collective Learning and Variety of Institutional Arrangements*. Dordrecht: Kluwer.

Schmitz, H. (1999). Collective Efficiency and Increasing Returns. *Cambridge Journal of Economics*, 23, 465--483.

Signorini, L. (1994). The Price of Prato, or Measuring the Industrial District Effect. *Papers in Regional Sciences*, 73, 369--392.

Squazzoni, F. and Boero, R. (2002). Economic Performance, Inter-Firm Relations and "Local Institutional Engineering" in a Computational Prototype of Industrial Districts. *Journal of Artificial Societies and Social Simulation*, 5, 1, *http://www.soc.surrey.ac.uk/JASSS/5/1/1.html*.

Staber, U. (2001a). The Structure of Networks in Industrial Districts. *International Journal of Urban and Regional Research*, Vol. 25, 3, 537--552.

Staber, U. (2001b). Spatial Proximity and Firm Survival in a Declining Industrial District: The Case of Knitwear Firms in Baden-Wurttemberg. *Regional Studies*, Vol. 35, 4, 329--341.

Stark, D. (1999). Heterarchy. Distributing Authority and Organizing Diversity, in J. Clippinger (ed), *The Biology of Business: Decoding the Natural Laws of Enterprise*, Los Angeles: Jossey-Boss.

Steine, C., Schiele, H. (2002). When do Industries Cluster? A Proposal on how to asses an Industry's Propensity to concentrate at a Single Region or Nation. *Research Policy*, 31, 849--858.

Torre, A. and Gilly, J.-P. (2000). On the Analytical Dimension of Proximity Dynamics. *Regional Studies*, Vol. 34, 2, 169--180.

Trigilia, C. (2001). Social Capital and Local Development. *European Journal of Social Theory*, 4.

Uzzi, B. (1997). Social Structure and Competition in Inter-firm Networks: The Paradox of Embeddedness. *Administrative Science Quarterly*, 42, 35--67.

Withford, J. (2001). The Decline of a Model? Challenge and Response in the Italian Industrial Districts. *Economy and Society*, Vol. 30, No. 1, 38--65.

You, J.–I. and Wilkinson, F. (1994). Competition and Cooperation. Towards Understanding Industrial Districts. *Review of Political Economy*, 6, 3, 259--278.

Appendix A: Parameters Structure and Initialisation

Since we are referring to an ID prototype, we think that a standard parameters analysis is not feasible. Because the prototype does not reproduce an identified empirical reality (i.e a specific and real industrial district), we can't rely on empirical precise data, collected or collectable, to define the "right" value of our parameters. Our model is based on some common and general concepts used like fundamentals able to identify the theoretical category of "IDs". The use of empirical evidences and case-studies literature allowed us to define such prototype fundamental mechanisms. Moreover such empirical sources allows the definition of the parameters structure. Parameters thus are not so "abstract", because they are linked by logical relationships which define every sign and value closely bounded up one to another. Finally, aiming to create an evolutionary model, the problem concerning the parameters exact value per se does not have a strong and bounding meaning taken by itself.

Therefore, it is important to show logic relationships among parameters, which bound their feasible space: the parameters structure emerging in this way is a component of the model and it must be considered as any other essential part of the model, such as the dynamics of technology, the production specialisation, proximity metrics, and so on.

The precise initialisation of the parameters (inside the possible range defined by the parameters structure) thus does not regard the link with empirical reality, but the simulation setting considered and studied. In the following paragraphs the parameters structure and the reasons of simulation settings are described.

A.1 Logic Relationships

A.1.1 Matrixes Parameters

Firstly, "TechMatrix" shows three values representing the cost of the production cycle for a firm (column A), the outcome value of production (column B) and a value representing the tiny saving on production cost for firms using over time the same configuration of technology (learning by doing and using – column C).

		T1			**T2**	
	A	B	C	A	B	C
0000	a_1	B_1	c	a_6	b_6	c
...	...	...	...	...	...	...
1111	a_5	B_5	c	a_{10}	b_{10}	c

Excepting the last parameter (c), which is always constant over time, for all the different technological situations, others are built with characteristics as follows:

- production costs and outcomes increase inside every technological regime ($a_5 > a_1$, $b_5 > b_1$ and $a_{10} > a_6$ etc...);

- outcomes increase faster than costs (i.e., the cost parameter increase the 1.4641% inside a technological regime, the outcome 1.74901%), in all the transitions from the worst technical asset (0000) to the best one (1111).

Moreover, different technological regimes are linked because the transition among them can be conceived as a radical change into the firm physical equipment, production management and human capital, namely all the different resources through which firms re-organise production processes. Therefore, it is plausible to conceive that the worst technical configuration (0000) inside a new technological paradigm, costs and produces less than the best one inside the foregoing one ($a_6 < a_5$ and $b_6 < b_5$).

Secondly, "ChangeMatrix" shows costs needed to implement a new technology (radical change), to change the firm internal asset (incremental change), and to establish and coordinate an effective relationship with partners outside the ID.

	T1	**T2**	**T3**
Technological change		d_1	d_2
Technical change	d_3	d_4	d_5
Coordination & Cooperation	d_6	d_7	d_8

Here, it is a main point to underline that costs for implementing a new technology are bigger than those paid for incrementing the technical asset ($d_1 > d_3$ etc...). Obviously, such costs are greater than those paid to produce a good (the "*a*" of "TechMatrix"), and they increase with the transition from the first technological regime, T1, to the last, T3 ($d_2 > d_1$, $d_4 > d_3$ and $d_5 > d_4$).

Moreover the cost to establish an effective productive partnership with external partners is even higher than changing technological equipment and internal organisation (for instance, $d_7>d_1$ and $d_7>d_4$), because external partnership implies an opening of the firm to a completely foreign production culture and a need of establishing a profitable communication with the new external partners, and of explicating the tacit knowledge widespread inside ID firms. Finally, this cost increases with the evolution of technology that becomes more complicated over time ($d_8>d_7>d_6$).

Thirdly, "InfoMatrix" shows information costs needed to gain the necessary information in order to implement a new technology, to improve the technical asset owned by firms, and to find new partners inside and outside the ID.

	T1	**T2**	**T3**

Technology imitation	e_1	e_2	
Technical imitation	e_3	e_4	e_5
Technology innovation	f_1	f_2	
Technical innovation	f_3	f_4	f_5
Best sub firm on technology	g	g	g
Best sub firm on performance	h	h	h

For both technological and technical change, gaining information through neighborhood imitation is cheaper than innovating, because of risks related to a direct exploration of the external technology environment; then $e_1 < f_1$, $e_3 < f_3$, etc... Moreover, information about a new technological solution is more expensive than information about simpler technical asset changes ($e_1 > e_3$, $f_1 > f_3$, etc...). Obviously, it isn't possible to find information about new technological solution inside the T3 phase. Finally, the parameter g is a constant representing the cost which final firms have to sustain for obtaining the "best" sub contracted firms available within the ID environment ($g=a_1$, the production cost with the worst technical asset). Inside the ID the "ranking" of possible partners is made according to the technological compatibility because such information is public (inside the ID) and cheap. When firms choose to externalise productive relationships, they have to sustain a bigger cost to find good partners ($h>g$), even if not so big because the selection process is based on a cheap and available information (but less accurate and superficial), that is to say the economic performance of external firms.

A.1.2 Other Model Parameters

Another relevant parameter is the one related to initial resources owned by agents. Initial resources are needed to make the simulation start. All the firms, final and sub contracted firms, inside and outside the ID, endow, at the start of the simulation, a number of 150 resources. It is a small value, given homogenously to all the population of firms, that lets them go on and start heterogeneous development paths, without giving too much resources that would unrealistically weaken the market selection. Secondly, there is a parameter called, in the code, "mrtc" that weights the time compression value, evaluating the possible gains coming from homogeneity of technological and organisational configurations of firms belonging to the same chain. The name stands for "marginal rate of time compression".

Moreover, two further parameters are the number of firms present and the length of the simulation considered (and on which is based the evolution of technology). The number of firms is set at one hundred for each category, inside and outside the ID. In this way there is enough space for heterogeneisation among firms and possibility to find enough alternatives in chain composition. The length of the simulation, 2,000 cycles, is set as a constraint, letting technological changes affect and select firms that aren't always sure to accumulate enough resources to implement and adapt new technological paradigms so to satisfy market demand.

A final parameter is in the last configuration of *H3* simulation setting, where 50% of the ID firms are set as belonging to the supporting institution. This stands for a way to test the presence of an institution which partially supports the ID.