

Pablo-Martí, Federico; Santos, Juan Luis; Gacía-Tabuenca, Antonio; Gallo, María Teresa; Mancha, Tomás

Conference Paper

Forecasting and simulation of the impact of public policies on industrial districts using an agent-based model

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Pablo-Martí, Federico; Santos, Juan Luis; Gacía-Tabuenca, Antonio; Gallo, María Teresa; Mancha, Tomás (2012) : Forecasting and simulation of the impact of public policies on industrial districts using an agent-based model, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/120619>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Forecasting and simulation of the impact of public policies on industrial districts using an Agent-Based model

Federico PABLO-MARTÍ, Juan Luis SANTOS, Antonio GARCÍA-TABUENCA

María Teresa GALLO and Tomás MANCHA

Instituto de Análisis Económico y Social – IAES, Universidad de Alcalá (Spain)

Abstract

There is abundant literature on the characteristics and success factors inherent in the industrial district. However, most of these works are focused on addressing the mechanisms that ensure the district be successful without properly treating the conditions enabling the activation of those mechanisms. The proper understanding of how, where and when emerge industrial districts, from an agent based model (bottom-up approach), allows characterizing more adequately the dynamics of the industrial district, and how public policies can affect the process, rather than traditional approaches that address the problem focusing on the district or system as a whole, simplifying and ignoring the dynamics of social processes that underlie the district.

Agent-based models make possible to tackle the analysis of complex phenomena, capturing processes not described by traditional techniques. The centerpiece is the agent, instead of the whole system. It also explicitly considered and modeled the heterogeneity of agents, their social interactions and decision-making processes. This paper presents the characteristics of an agent-based model, which reproduces the dynamics of industrial districts and predicts the effects of public policies on their operation. This model is an adaptation of model MOSIPS (MOdel of Simulation of Impacts of Public Policies on SMEs).

We present a number of recent empirical works on this methodology applied to the study of industrial districts, and emphasize its convenience and potential. Then, we describe the simulation model of the industrial district showing the characteristics of the agents, the environment, social interactions, actions that agents perform, and decision rules that are part of modeling.

Key words: Agent-based model, industrial districts, simulation, policy evaluation

JEL: L52, R12, R58

Acknowledgements The work presented in this document has been conducted in the context of the EU Framework Programme project with Grant Agreement 288833 MOSIPS (Modeling and Simulation of the Impact of public Policies on SMEs). MOSIPS is a 36 months project started on September 1st, 2011.

The project consortium is composed by: Anova IT Consulting (ANOVA), Universidad de Alcalá (UAH), Research Studio Austria Forschungsgesellschaft (RSA), University of Reading (UoR), Opera 21 (Opera21), University of Konstanz (Konstanz), European Institute of Interdisciplinary Research (EIIR), Ayuntamiento de Madrid (MUNIMADRID) and Comune di Verona (VERONA)

1. Introduction

The Industrial District (ID), initially introduced by Marshall in 1919, is defined as a geographically localized production system, which is based on a division of activities among specialized companies in different phases of production and distribution within an industrial sector in a dominant activity or in a limited number of activities. The existence of network externalities is the key factor for the competitiveness of the local system comprised of Small and Medium Enterprises (SMEs). Becattini (2002) also considers the ID as a socio-territorial entity, with an active presence of both a group of people as well as a set of companies in a natural and historically determined area. Its effectiveness and potential depend on relational systems that structure the district. Accordingly, the ID will be characterized by a dense and strong network of relationships among autonomous and heterogeneous agents (firms, families and local institutions) (Iandoli et al., 2012).

Based on the review of the current state of research on clusters and IDs (Martinez et al., 2012) one can say that what has prevailed in recent years have been the traditional approaches on the functioning and performance of the district but they have important drawbacks. Firstly, they take as the starting point the existence of the district, without analyzing the conditions or mechanisms involved in their origin. Moreover, their identification is made from aggregate indicators as evidence of the advantages of its operation. Lastly, it is assumed the existence of networks within the district as one of its characteristic features. These approaches offer support for the analysis of IDs but only to a limited extent, because they are not designed to address situations where "what if" questions related to changes in certain conditions or parameters are crucial (Kiesling, et al., 2012).

Traditional approaches do not permit us to understand in depth the nature of the complex and imbricated existing relations in the district, nor the mechanisms that promote the agglomeration of small businesses in the area and originate the district. However, as it is addressed in the latter economic literature, a different perspective of analysis of industrial districts is possible via agent-based simulation. This approach is based on the study of the districts as complex and adaptive systems. It is feasible to replicate their features from the interaction of autonomous agents with bounded rationality, in a virtual environment composed of resources and constraints (Iandoli, 2012).

The purpose of this paper is to show the scope of agent-based models with respect to the analysis of the dynamics of functioning and performance of industrial districts. Then, it is outlined an approach of a methodology to simulate and predict the impact of public policies on the performance of the ID, derived from a more general model developed to

simulate and predict the impact of public policies on small and medium enterprises (Model of Simulation of Impacts of public Policies on SMEs - MOSIPS).

This work is divided into four sections including this introduction. The second part presents a brief review of recent theoretical and empirical works based on agent-based models and their application to the study of industrial districts, in order to show the scope of this methodology, as well as to identify key limitations to address them in future research. In section 3, we illustrate the proposed modeling to assess the impact of public policies on IDs from MOSIPS model. The expected results of this modeling and some final considerations on the approaches developed in the previous sections are presented in section 4, which highlights the advantage of having real data to simulate the dynamics of industrial districts.

2. Dynamics of industrial districts. The scope of the agent-based modeling

2.1 The suitability of agent-based models for the study of industrial districts

The inherent characteristics of industrial districts allow their consideration as complex adaptive systems or emergent complex phenomena, defined by the existence of a growing network of heterogeneous agents, localized and integrated functionally (Iandoli, et al, 2012; Albino, et al., 2006). The interaction between the agents is nonlinear, and they can adapt themselves, learn, evolve, and even develop some self-organization mechanism that allows them to acquire collective properties or characteristics that do not have individually. Consequently there will be outcomes arising from the interaction between agents and between them and the environment in which they operate (bottom-up approach). In other words, aggregate macroeconomic results emerge from the behavior of individuals that take part in these complex environments. The properties or resulting patterns are unknown before the simulation has taken place (Giardini et al., 2008).

This kind of systems can be methodologically approached through agent-based models (ABM), offering the possibility to study in depth the dynamics of IDs into phases or specific processes that affect their operation, such as: 1) creation 2) development and maturity, 3) coordination and cooperation mechanisms, and 4) innovation processes, among others. The core element is not the social system as a whole, but the individual or agent. It is also possible to model explicitly the heterogeneity of individuals or agents, their social interactions and decision making processes in order to delve into the mechanisms that allow trigger the formation of IDs and their development or decline.

Their attractive also lies in the fact that they reproduce the behavior of real world through the development of simplified models which can be used to explore the behavior of these artificial systems and predict what would have happened in the reality. This enables the researcher to repeatedly modify the model parameters and observe the changes occurred. And finally, their application may fill several purposes such as prediction, performance, training, education and hypothesis confirmation (Albino, et al. 2003).

Two aspects become crucial and may influence the results: i) the behavior of agents, and ii) the social influence (Kiesling et al., 2012). Modeling the behavior of agents or the decision-making process is related to specific decisions as the location, the creation of the district, the decision to cooperate, the implementation of an innovation, etc.

The modeling of these decisions can be based on: i) the application of simple decision rules (such as taking a decision as soon as the first known agent have already done); ii) the use of utility approaches (where the ‘utility’ is an interpretative label rather than explicitly modeling the election among alternatives); iii) the use of transition states approach through a dummy variable indicating the status of agents, such as "potential adopter innovation" and "innovative" or as a sequence of a path of multiple states such as ‘seeking information’, ‘implementation’ or ‘dissemination’; iv) the approaches related to the dynamics of behavior, in which preferences are established in the process of collective opinion formation (the initial decision of the agent is updated from the observed behavior of their neighbors); v) the approaches of the social psychology, where decisions are based on psychological rules rather than perfect rationality; and vi) the econometric estimation of each choice probability (for example through a microdata panel to estimate the probabilities of individual choice according to the individual characteristics).

The second aspect of the modeling, the social influence, involves a number of features: i) the level of social influences: micro- local spread word of mouth; meso- any influence coming from the immediate social environment of the agent-; and macro- interactions with the society as a whole; ii) the interaction types (social networks in which interactions take place, models of random graphs, and small worlds or highly clustered networks); and iii) the qualitative modeling of social influence (dissemination of information of an innovation, positive or negative word of mouth diffusion, the agents can share their decision since it was taken).

Therefore, the more information available at the time of establishing how the decision-making processes is carried out and the impact of social influences on these decisions, it will be more accurately reproduced the performance of the district.

In ABM models agents are active entities target-oriented, which have certain capabilities to perform tasks and interact with other agents. In other words, each agent has a "mental model" (Albino, et al., 2006) consists of: 1) their objectives, 2) the "social memory" with the knowledge about the social behavior of agents, 3) the "working memory" with the knowledge about the capabilities of agents, and 4) the rules of social engagement that are defining the social behavior of agents. Therefore, the agents perform a set of actions to achieve their goals and they can learn and adapt themselves to their immediate environment.

The empirical works in which ABM methodology has been applied to the study of industrial districts are not abundant. However, some few studies show its recent application to this area and provide a reference point.

This methodology offers the possibility of analyzing the evolution of industrial clusters from the consideration and explicit modeling of different micro aspects that influence crucially on the geographical concentration of enterprises, from the simulation of the spatial dynamics of the entries, exits and growth of enterprises in these clusters. Overall, companies of industries which have high growth rates of startups, radical innovations, spin-offs located close to business incubators, venture capital provided by existing companies, and those which can take advantage of synergies local businesses of the same industry, appear more likely to agglomerate (Brenner, 2001).

In recent years, models of innovation and technological change appear to be the ones which have attracted the attention for the application of this methodology in the field of industrial districts, both with theoretical and empirical approaches. The purpose of this methodology is not only to provide explanations for several stylized facts empirically established, but also as a method to reveal the properties that characterize innovation processes in the field of industrial districts. Among these properties, it could be cited: 1) the dynamic structure of the innovation process; 2) the singular nature of knowledge and spillovers; 3) the uncertainty which characterize the design innovations in technology searching and the prediction of market responses; and 4) the importance of heterogeneity in innovation strategies (Dawid, 2006).

The different coordination mechanisms which activate the cooperative and competitive relationships found in the ID can be also analyzed through the application of ABM models (Albino, et al. 2003; Albino, et al., 2007). The simulation analysis are performed to verify the benefits of cooperation for the agents involved in the industrial district, and to assess those advantages within different competitive scenarios and upon several organizational structures. In this sense, the characteristics of the industrial district are contained in an ABM which includes multiple autonomous agents who can learn and communicate between them.

The framework of the model includes: the *agents*, the *interaction infrastructure* between each kind of agent, and the *organizational infrastructure* (based on three hierarchical levels, the enterprise level, the level of the production phase, and the level of the industrial district). The district can be studied under two scenarios, including the presence of cooperation and the lack of it. Thus, it can be studied the differences in the demand satisfaction, production capacity utilization and the results of utilization of the production capacity of the supplier.

The economic performance of an industrial district depends on how companies interact and coordinate with each other. This feature is considered, and confirmed by these models. Their scope permits also analyze how different local institutional and their decisions can affect the economic performance of the ID (Squazzoni and Boero, 2002).

The study of reputation, defined as social assessment carried out by agents on several aspects such as product quality, selection of partners and the penalty of deceivers, can be tackled through ABM models in order to determine how these assessments affect the dynamics of industrial clusters (Giardini et al., 2008). Reputation is understood as a highly dynamic phenomenon subject to changes after events of fraud, errors, or disappointments and it is the result of bidirectional processes at multiple scales. It is characterized by its impersonal nature, as it is a social attribute arisen from the dissemination of cognitive representation. Modeling the reputation of agents of the ID allows determining the extent to which social assessments may be related to the quality of the products and the cluster characteristics. In this environment two different types of interactions between firms are identified: trading products and raw materials, giving rise to the supply chain, and on the other, sharing social evaluations and creating social networks.

It has also been analyzed applying ABM models the conditions which the needing of sharing knowledge results in the creation of social networks (Iandolfi, et al., 2012). In contrast to most of the analysis, where the existence of networks of firms is assumed to be given, this kind of approach explores the mechanisms that allow the creation of steady networks between companies in the district.

The role of proximity in the broadest sense (geographical, organizational, cognitive and social) on the competitiveness of IDs is another area of analysis of agent-based modeling applied to industrial districts (Carbonara and Giannoccaro, 2011). In order to determine the optimal combination of proximity degree that promotes the competitiveness of the ID, are identified a set of structural characteristics of the district over proximity can have an impact. It is suggested, when firms in the district become too "close" the district's adaptive capacity decreases and their competitiveness is reduced. However, organizational proximity between companies in the district shall be

reduced in order to increase their competitiveness. Also, if there is high competition between district firms, companies can be closer geographically and cognitively and their adaptability is not affected. If trust is an important factor within the district, organizational proximity should be lower, and finally, if there were research centers, firms belonging to the district can be closer geographically and cognitively, without losing their adaptive capacity (Boschma, 2005).

From this brief review, it is clear that the main limitation of the referred works is they analyze some partial aspects of the operation of industrial districts (such as cooperation mechanisms, the dynamics of reputation, etc.), addressing in a restricted way the dynamics of ID. In addition, interactions with individuals or families that are involved directly in the district are not taken into consideration. Individuals and families determine the operation of IDs, as they are entrepreneurs, workers with human capital and final consumers of the production. Networks are formed by firms, but also by individuals, sharing information and developing learning routines.

On the other hand, the referred works make use of randomly generated data. Although they constitute a point of reference for future research they are inefficient at the time of getting valid conclusions about the actual processes or phenomena under study. Finally, the consideration of the impacts of policies on the performance of firms, and the industrial district as a whole, not only through the cost function, but also by changes in the agents' characteristics, and their own behavior, becomes another area in which the agent-based models can provide important findings and empirically confirm some facts established in theory.

2.2 Components to be modeled in the analysis of industrial districts

The application of agent-based models to analyze industrial districts requires specifying the following features: 1) agents, 2) the environment, 3) interactions, 4) actions, and 5) decision rules.

With regard to *agents*, it is noteworthy that firms are the principal agent to model. However, it will be also considered certain features inherent to individuals in their role as employers and employees, as they may be crucial in the dynamics of the ID. It is necessary to specify firms' characteristics, the products developed, production processes carried out and the objectives pursued. It is also possible and it can be useful to define a typology of agents accordingly to their characteristics and the role they play within the district (for example, it is possible to identify leading companies, followers, competitors, or suppliers).

Regarding the *environment*, we can identify the following components: customers, universities, research centers, technology production centers, local governments, financial institutions, etc.

In terms of *interactions*, in the modeling process should be detailed the mechanisms that guarantee the existence of networks between agents and between agents and the environment, as well as the characteristics of such networks. That is, in the case of networks between agents, it is possible to identify the trading of goods, information, knowledge and technology, while in the networks between agents and the environment, we can identify the networks formed by companies with customers, research centers, technology production centers and local public administrations.

Different types of *actions* can be performed by the agents that are part of the ID. These actions have a probabilistic nature and depend on the characteristics of the agents (learning ability, adaptation and specialization) and on the interactions between agents and between agents and the environment, which modify the available information and knowledge. Agents can learn depending on their location and specialization, also from the interaction with suppliers or with research centers, or the interaction with customers and competitors to react to local supply and demand.

Finally, *decision rules* deal with two central issues. They establish when actions occur, and how they operate and the mechanisms to carry out these actions are activated. For example, learning from interaction with customers is activated by contact between customers and companies, producing incremental product innovations that depend on the skills of firms and their ability to capture market signals, or, learning from interaction with universities and research centers that depend on the proximity of the business to these centers, and which activates when the company shows a high propensity to cooperate provided with high skill levels and resource availability, producing radical innovations in product and process. (Albino et al., 2006).

Another element to take into account when modeling is the creation of possible *scenarios* from which the results can be simulated. As an example, in the case of social assessments about the industrial district are considered two scenarios. In the first one, agents share true or false opinions about the supplier. It may affect the acceptance or refusal to carry out a transaction. And in the second one, the choice of provider will be solely based on the own experience of the agents, because any type of communication or interaction is not allowed (Giardini et al., 2008).

This allows policy makers designing and running experiments with different socio-economic scenarios. The project focus is on SME-oriented policies in order to structure the scope of its R&D activities and demonstrate the policy impact and valorization potential. Three concepts arise as major areas to take more into account: productivity, innovation and competitiveness of SMEs.

Summarizing, MOSIPS model represents the dynamics of behavior and decisions of agents, and their interactions. It forecasts the evolution of an economic system over a time horizon of one quarter to several years. It is based on a multi-agent approach at the micro-economic level. It can be used to model macro-economic features of a system and allow focusing in a specific part of the economy, at sector and spatial level, evaluating the effects of a policy over the firms and the individuals, depending on their initial characteristics. The concept of industrial district arises as a leading figure in which there are combined concepts such as localization and innovation, key for the performance of the different actors that are part of the socio-economic reality.

MOSIPS model provides the framework to test the accuracy of micro-foundations specified outside the scope of the representative agent paradigm reproducing a virtual reality to evaluate the effects of economic policy. The obtained results have a range of error due to the randomness of individual processes and the building of the database. This approach can be seen as an extension to Arrow-Debreu general equilibrium theory (Arrow and Debreu, 1954), as the unique result computed by standard models is one of the possible outcomes: the optimal trajectory excluding part of the heterogeneity of the agents, and not having into account spatial issues with a sufficient degree of accuracy.

The object of study is a local economic system, disaggregated by branches, which represents the economic system under consideration. Then, the effects of a policy are studied both at sector and at spatial level. These effects also can be observed according to other characteristics such as the size of the firms, their innovative behavior or their financial situation. The effects of policies can also have an effect into the population, and they can also be studied taking into account their location or the individual characteristics. These heterogeneous agents can be part of one of the industrial districts existing in the economy. Thus, it can also compute the effects on the district, defined as an entity formed by the aggregation of interconnected individual agents who cooperate among themselves.

3.2 Simulation of the dynamics of the industrial district

Based on the previously presented MOSIPS model, some of its elements are characterized, stressing the ones which take part in the dynamics and performance of industrial districts. Agents belonging to these districts can be of every kind present in the model, and they will be part of the district accordingly to their behavior and their

relationships with other agents. The environment is also part of the districts, encouraging their development through actions carried out by public administrations, finance enterprises and knowledge-generating institutions. The actions carried out by the different actors, mainly the location and innovation decisions trigger the formation and affect the development of industrial districts, which emerge through the repeated interactions. So the model can also shed light about the decision-making processes of all actors involved in the district.

3.2.1 Agents

The model considers two main kinds of agents: *firms and households*. The first ones are formed by a number of establishments, while households are groups of individuals. Some of their decisions are taken autonomously by their components, while others are decided by the group. Every agent has the characteristics pointed by Wooldridge and Jennings (1995). They decide their characteristics autonomously trying to maximize their expected profits or utility. The communication among agents takes place by market prices and social networks. Agents react to the changes in their environment, but sometimes anticipate these changes in order to define their decisions, showing a proactive behavior.

The analysis is focused on entrepreneurs and companies. They have different behaviors depending on their risk aversion or their proactivity and reactivity degree. These agents take business decisions that affect both their performance and the results of competitors, and have an impact on the economic activity. There are a plenty of interactions with other agents of the same kind, for example establishing trade relations between them, or with other kind of agents, employing workers or selling their production to consumers, among others. Moreover, there are partnership between companies, so that sometimes form pairs, groups or clusters of companies whose objective is to achieve a common goal (for example in order to carry out innovation or exportation activities).

In addition, firms can be considered from the perspective of the individuals which conforming them. That is, from the different degrees of responsibility and ability to take decisions that hold individuals belonging to a company. Thus, one can distinguish workers, technicians, managers, directors and owners. This approach underlie in the theories on human resources and knowledge management (Yahya and Goh, 2002). Each individual who is part of the company takes management initiatives in accordance to the objectives of the firm, or even may exhibit opportunistic behavior, trying to maximize his outcome. These behaviors treated individually (each member of the company is an individual) would lead to a result not always optimal, but realistic as includes the complex relations between firms as a whole and individuals who are part of them.

3.2.2 Environment

The environment of the industrial district is formed by other firms with the same characteristics of the ones part of the district, households that have a role different from firm owners or workers within the district, finance institutions, universities and research centers and local administrations.

Households are composed by a person or a couple with their dependent descendants living altogether. They are agents formed by individuals; each agent category exhibits a number of different attributes. Households determine their expenditure as a whole, although individuals obtain their income on their own. Households usually move entirely, but not always, creating several new households in the process. People living in the same household have the maximum possible economic interaction level, not only due to the housing share, but because they are part of the same family. Individuals have also interactions with other individuals as their neighbors and their work colleagues.

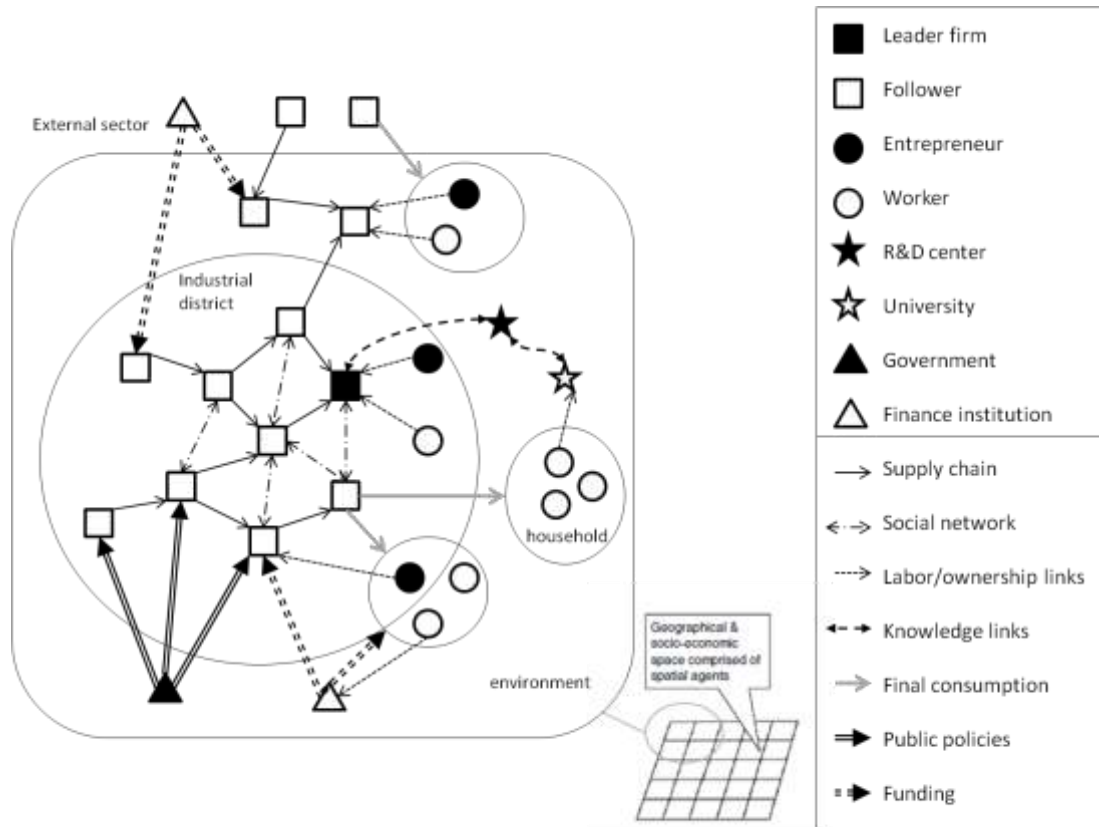
The remaining components of the system are not agents because of the lack of have some of the properties of agents, as proactivity and autonomy. They are complementary entities involved in a greater or less degree in the modeling process but which are indispensable in its configuration. The evolution of their decisions clearly affects agents' behaviors pattern by creating expectations and affecting decisions of the companies and individuals in the district. The most significant are the government, composed by national and local authorities, the organizations and companies in the financial sector and knowledge based institutions.

The government includes all the public figures which have the political ability to influence the macro and microeconomic environment through the adoption of new standards in the economy. For example, they can change the official interest rate, set the age of retirement, or create a technological park in a campus. Moreover, they have the authority to enforce the payment of taxes.

The entities in the financial sector are banks, except the Central Bank, which is considered part of the public administration, and other financial institutions whose purpose is to intermediate flows and funding needs of other economic agents present in the model: companies, entrepreneurs and workers, families and additionally, government and public administrations and the external sector.

The agents and the environment involved in the district as well as the nature of the relationships among them are described in Figure 2.

Figure 2. Agents and environment incorporated in ABM of Industrial Districts



Source: Own elaboration based on Albino et.al (2007) and Tsekeris et.al. (2011)

Apart from the defined local environment, there are foreign agents (firms, consumers, financial sector, and trade sector). They are interconnected with agents belonging to the industrial district and others of the local environment. They can be modeled as a single aggregate agent, which can be understood as the aggregate supply of foreign products or the aggregate demand for exportations.

Finally, a raster of locations allows the placement of every agent, and helps to establish the links between them in a more realistic way in comparison with other approaches that do not have the spatial perspective into account. Thus, families only demand goods and services near their residence and their workplace; however, they can buy often in other areas as the downtown. Individuals working far away of their residence will tend to move either from their house of or from their job, as they tend to be displeased. From these kinds of interactions arise some attributes of the locations that affect the agents of the system: The degree of competence in an area and the density, among other factors, are determinants of the level of prices.

3.2.3 Interactions

As we described in Figure 2, the kind of interactions that structure the relations between agents have different nature according to the agents that form part of them, and the activity or characteristic that links them. These relations are developed based on the various activities undertaken by companies in their recruitment and procurement of inputs, human resources management, production, innovation and technology management, product development, financial management and business strategy sales. Individuals establish their relations with firms from their consumption and saving decisions, employment and ownership. Social relations with other individuals take place through companies (co-owners, work colleagues, etc.) or with some of their relatives and neighbours.

In the modelling process, the properties of the protocols that govern the interaction between individuals and companies are based on relations of production and consumption, employment and lending, adopting a microeconomic perspective (see figure 3). In this sense, the price of competitors' products in relation to themselves constitutes one of the main signals received by the agents. They act taking the suitable decisions for the acquisition of inputs, recruitment of factors, production and sales. These relations take place in markets.

With respect to these factors and product markets, the model provides an approaching to local environments. But it also assumes the existence of other broader environments, at national or international level. That is, the analysis of interaction of agents is focused on their interest in a defined territorial space, such as a region. Relationships with agents from other areas are analysed in a more simplified approach. For example, the majority of goods are bought by large retailers in international markets, and then they sell them to small retailers. Final customers do not have access to a high number of sellers due to informational costs. Then, the appropriate scale of the first market is international, small retailers only have access to the regional market and final customers tend to purchase goods at local level.

The same assumptions are made in the relation between firms and workers, who are unemployed or employed in other companies and they want to change their jobs. It could be considered that both companies and workers face the regional employment supply and demand, respectively. Mostly of the approaches assumed that all the agents act against the market, the aggregate behaviour of the rest of agents, looking to optimize their interest. However, occasionally, every agent creates its own behaviour associated to the decisions of its neighbours. It arises from the information and expectations generated by the rest, weighted depending on their spatial and relational proximity. For example, a company located in a municipality is able to produce and sell its production

with a slightly different price from a competitor of a neighbouring municipality, while in other part of the region prices can be lower. Then, agent actions and decisions are highly affected by the behaviours of agents in the proximity, but it also depends on the aggregate behaviour, emerged from the decisions of every agent.

Thus, all companies are somehow interconnected, but these links are stronger in environments which are closer. In any case, those behaviours associated with the environment may also depend on the sector, the concentration of supply and demand or the degree of public promotion of a product (e.g., which is derived from the impact of advertising).

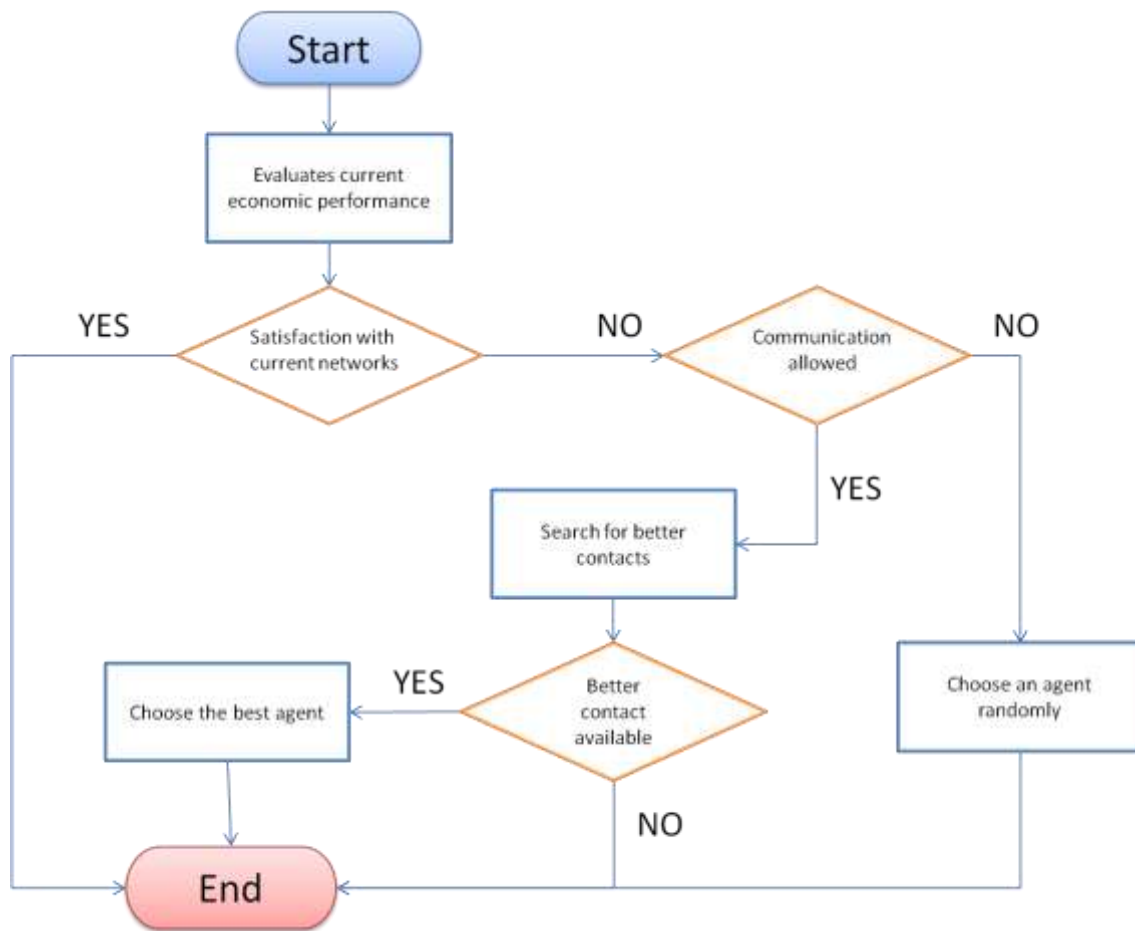
Individuals face the same interaction protocols and information flows, but applied to their decisions. They obtain most of the information from firms which they are linked, but also from the aggregate behaviour (e.g. the unemployment rate, GDP growth, price index). Individuals' decisions are also conditioned by the performance of other agents who are linked with. Then, a potential entrepreneur will decide to create his own enterprise with a higher probability if both their acquaintances and the information about the general performance of the economy is promising for the success.

3.2.4 Actions and decision rules

Every agent carries out a plenty of activities. Many of them can be taken by more than one kind of agent. This happens with firm performance decisions such as location: while decisions in small businesses are controlled by the owner, big corporations have managers, who optimize its behavior accordingly to the strategy of the firm.

Firms take decisions about their production level, number of employees, assets and liabilities structure, and their location. Additionally, they select their suppliers. This process is equivalent to labor or consumptions elections. Firstly, the agent evaluates its performance. For this purpose, it examines not only its results, but also receives information about other agents, which can be biased and incomplete. If the performance is sufficiently good, the agent does not search for new agents (suppliers, workers, etc), whereas if its performance is not sufficiently good, according to the expectations of the agent, or worse than the average perceived performance, the firm will look for better agents to work with (Figure 3).

Figure 3. Social links formation and updating process in Industrial Districts

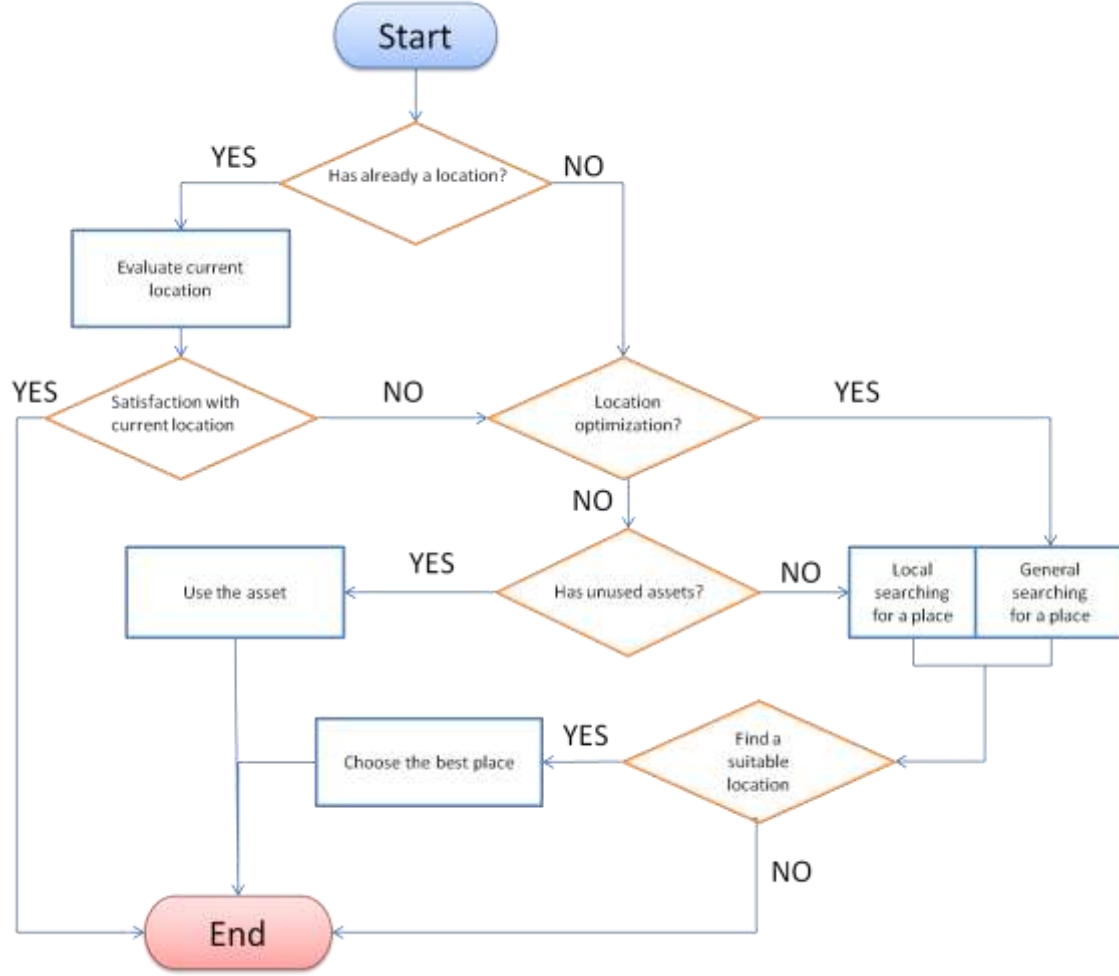


Source: Own elaboration based on Giardini et.al. (2008)

A similar process takes place to determine the location of every establishment. Each one must be located in a single cell of the raster. Small firms cannot optimize the location, as they are influenced by the entrepreneur decision. The owner may have an unused asset that chooses to use or may start a local search near its residence.

If the establishment is already located, the firm evaluates the current location in order to decide if it should be modified. For this purpose, it evaluates its performance with respect to other establishments of the firm and the information it has from other companies. Thus the firm may start a location optimization process through a general or local search of a suitable location (Figure 4).

Figure 4. Decision on location of establishments



Source: Own elaboration

Further the formation of social networks within the industrial districts and the decisions on location of establishment, ABM can reproduce the dynamics of the innovation in IDs.

Firms innovate to increase their productivity in order to continue being competitive and survive in the market. Every firm belongs to an activity branch and products a good. Starting with the scheme stated by Brenner (2001), a_i the productivity of a firm i is defined by:

$$a_i(t) = \left(\sum_1^{n_1} \frac{a_j}{n_1} \right) T_i(t) (1 + C_i(t)) (1 + M_i(t)) P_i(t)$$

$$a_j = \left(\sum_1^{n_2} (1 - \delta_1)^{n_2} (s_j + \sum_1^{n_3} Q_{n_3} w_{j,n_3}) \right)$$

$$T_i(t) = (1 - \delta_2)T_i(t-1) + R_i(t) + S_i(t)$$

T_i is the state of the technology of firm i . It is the result of the previous state of technology with a discounted factor representing obsolescence. To this amount is added the result in period t of previous R&D investment $R_i(t)$ and technological spillovers from leader firms to firm i $S_i(t)$.

$$S_i(t) = AC_i \sum_{l=1}^l (1 - \delta_2)T_l(t-1)CP_{i,l}(t-1)$$

These stochastic spillovers are the result of interactions between firms, and they are more probable to take place between long-time linked firms of the same sector, located in close proximity, when at least one of them is one of the sector leaders. They are determined by AC_i the absorption capacity of firm i , and the state of technology in the previous period of leader firms T_l with which the firm has a positive value of cognitive proximity $CP_{i,l}$. This variable is an approximation of the degree of relation between two agents. It includes not only the spatial proximity, but the level of relation, defined as the intensity of the direct contact of the agents and the number of second-degree links.

Innovations can be produced when several firms cooperate (C_i). Cooperation processes are more probable within industrial districts, where business associations have a higher weight. Each firm can be present in one or more cooperation networks, and depending on its participation in these networks it has an increasing value of this variable. Cooperating has a cost assigned to the members of the network. Firms determine if they want to participate in this process and share the results with the rest of the group, or want to innovate on their own. Cooperation networks have a role not only for innovation purposes, but for advertisement, exportation and to reach agreements with the suppliers.

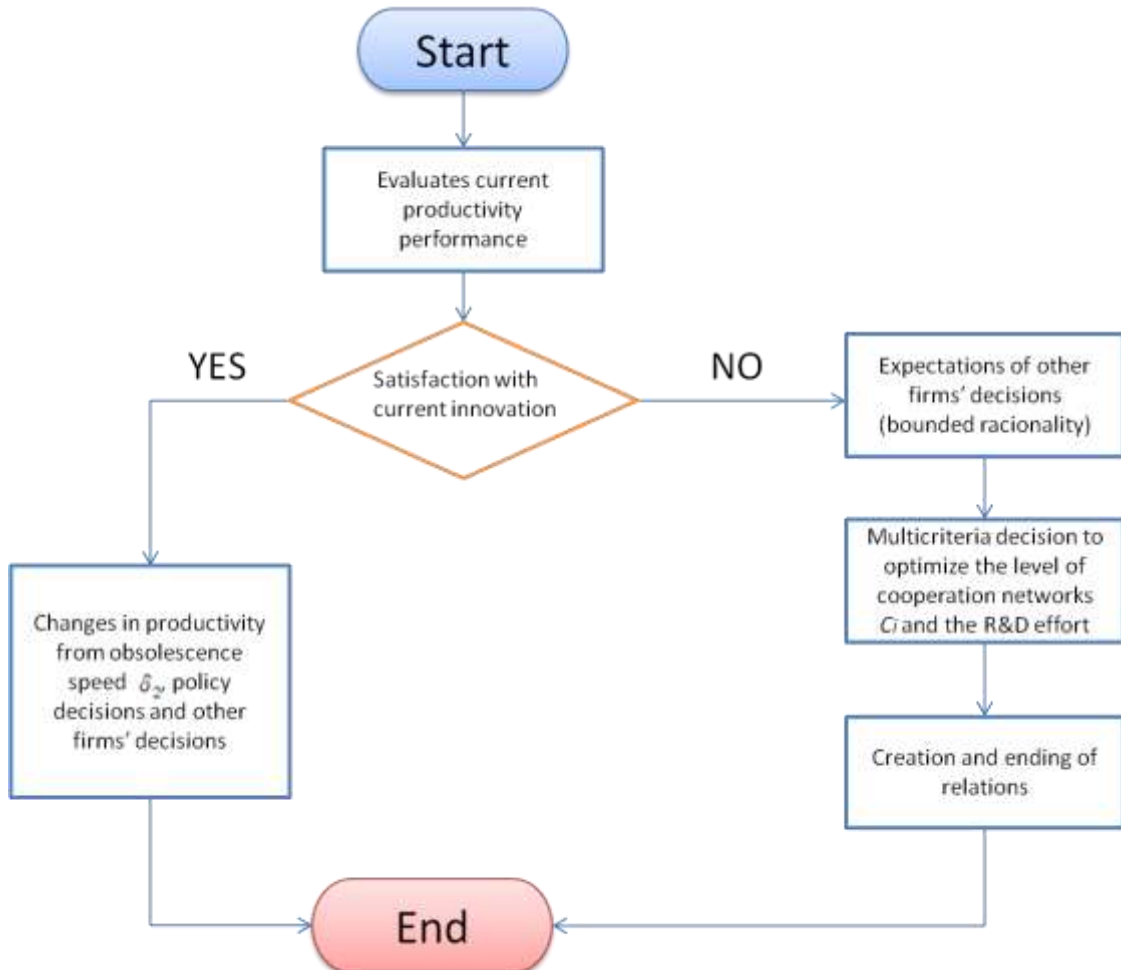
A firm located away from any other would have not positive benefits from the rest of firms of the region, represented by M_i . These benefits come from a plenty of interactions different from cooperation, technology spillovers or employee performance. They are the result of a supply cost reduction, scaling and visibility. An increasing number of near enterprises permits an efficient provision of raw materials and products for delivering. A part of this reduction in the costs can be captured by this group of firms, depending on their market power. Additionally, each enterprise increases the visibility of the near firms of the same sector. Thus, agglomeration processes have two opposite effects. On one hand they reduce the potential demand of every firm, but on the other hand, all the firms become more visible, and attract farther located consumers than a firm on its own.

$$V_i(t) = \left(\sum_0^{n_4} (1 - \delta_3)^{n_4} (size_i(t - n_4) + adv_i(t - n_4)) \right) + \left(\sum_1^{n_5} size_{n_5}(t) SP_{i,n_5}^2 \right)$$

The visibility of each firm (V_i) is determined by its current and past size, and its advertisement effort (adv) from the period j up to the present. Oldest outcomes of these variables have less impact on the visibility. Agglomeration increases the value of this variable, adding the current size of the k nearest firms, weighted by the spatial proximity ($SP_{i,k}$).

Finally, the parameter P_i reflects how public policies affect the productivity of firms. If policies are neutral to the productivity, it takes the value one. Policies affecting the determinants of research investment and human capital formation will reduce P_i down to zero. This minimum represents the total prohibition of the activity. Political support to innovative initiatives increases this value in the amount of percentage variation of total productivity in the period.

Figure 5. Decision on innovation of firms in the Industrial District



Source: Own elaboration

In Figure 5 is described the process in which firms perform the innovation decisions. Firstly, they proceed to evaluate their current productive performance. They compare their productivity with their estimations of the one of other firms in their sector. If their performance in comparison with their perception of their competitors is not adequate, they adjust the levels of R&D investment, assess the establishment of new cooperation networks and change their relations. These decisions are simultaneous and they implement them in accordance with their expectations of other firms' activity.

When the firm consider satisfactory its level of innovation, its productivity is only affected by changes in the obsolescence speed, other firms' decision, as ending their relationships, and by the effects of changes in public policies.

In addition to the previously pointed interactions, activities and decisions, agents have learning processes, which are represented by the changing of several structural characteristics (consumption patterns, mark-ups or technology) of households and firms. These processes are carried out by imitation and also by mutation procedures.

Agents tend to imitate other ones of their same kind which are in their network and show a better behavior. Not always the adoption of a new behavior is positive, every so often the better result obtained could have happened by chance. Thus, imitation has not always the desired effects. Additionally, a previous successful performance does not warranty current or future success because of the unforeseen or unexpected sharp changes in the economy. A good example is found in the real estate sector during bubbles. It shows high profits during a certain amount of time, but the last starters only achieve losses.

Mutation introduces innovation in the system. On average, proactive agents will have an aggregate poor development, but some of them initiate profitable behaviors. Proactivity is not a characteristic present in every agent, as it requires a certain level of initiative and a relative low risk aversion.

3.3. Public policies

The model permits the study of almost any policy that the public administration implements which has effects on SMEs, not only the policies designed specifically to encourage business activity. All the principles included in the Small Business Act (European Commission, 2008) have been taken into account and turned into a concrete set of policy domains. Then, the model allows the inclusion of any policy related to entrepreneurial activity, infrastructure, innovation, internal managing, inter-firm

relations, labor market, funding, relations with the administration, environment and macro-economic environment such as changes in taxation or trade restrictions.

These policy domains can affect the agents in three different ways, as it is shown in Figure 6. They can change their cost function, their characteristics (data) or their behavior. They affect the performance, development and decay of every industrial district present in the economy, as well as the processes undertaken between the components of the district such as cooperation, competition, innovation and knowledge dissemination.

Figure 6. Illustration of policy domains included in MOSIPS model.



Source: Own elaboration

Every policy domain can affect agents in a plenty of ways. Thus, the effect of a policy enters in the model in several of the modules pointed in Figure 1. Every policy included can have a disperse effect on many agents, or focus on a small number with specific characteristics. The effects of policies are extended in the system over time, and even policies in principle outside the industrial districts may have far-reaching impact on them.

4. Expected outcomes and concluding remarks

A number of outcomes may result from the application of the proposed agent based model of the industrial district described in the previous sections.

First, in contrast to the traditional approaches, the model offers the possibility to determine the existence of an industrial district analyzing the main characteristics of the involved agents and their interactions. Rather than assuming a priori the existence of an

industrial district, this approach allows a more accurate knowledge about the necessary conditions to its emergence as well as facilitates a deeper understanding about its operation and dynamics of its evolution.

Second, some of the main aspects that define the industrial district -as the location decision, the emergence of social network and the innovation processes - may be approached by the application of the proposed model. The richness of information derived from the agents' behavior, their interactions, their decision rules, and the impact of the environment allow dealing with the characteristics of a more complex system. Heterogeneous, autonomous, reactive and proactive agents with bounded rationality are in the base of the logical operating of the model.

Third, the impact of public policies on small business enterprises that are involved in the industrial district is another key outcome that can be derived from the application of the model. In this context the possibility to deal with “what if” questions allow focusing in the aspects in which policies may produce the more relevant impacts.

Finally, the opportunity to deal with real data –by the development of the MOSIPS project- makes the model a powerful tool to simulate and predict the emergence, the functioning, the evolution and the decline of the industrial district based on real characteristics of the agents involved in them within a particular territory.

References

- Albino, V., Carbonara, N. and Giannoccaro, I. (2003). “Coordination mechanism based on cooperation and competition within Industrial District: An agent-based computational approach”. *Journal of Artificial Societies and Social Simulation* vol. 6, n4 <<http://jasss.soc.surrey.ac.uk/6/4/3.html>>.
- Albino, V., Carbonara, N. and Giannoccaro, I. (2006). “Innovation in industrial districts: An agent-based simulation model”. *International Journal Production Economics*, vol. 104, pp. 30-45.
- Albino, V., Carbonara, N. and Giannoccaro, I. (2007). “Supply chain cooperation in industrial districts: A simulation analysis”. *European Journal of Operational Research*, 177, 261 – 280.
- Arrow, K.J. and Debreu, G. (1954). “The existence of an equilibrium for a competitive economy”. *Econometrica*, n° 22, pp. 265-290.

- Becattini, G. (2002). "Del distrito industrial Marshalliano a la teoría del distrito contemporánea. Una breve reconstrucción crítica". *Investigaciones Regionales*, no.1, pp.9-32.
- Boschma, R. A. (2005). "Proximity and Innovation: A critical assessment". *Regional Studies*, vol.39, no.1, pp. 61-74.
- Brenner, T. (2001). "Simulating the evolution of localized industrial clusters – An identification of the basic mechanism". *Journal of Artificial Societies and Social Simulation* vol.4, no.3 <<http://jasss.soc.surrey.ac.uk/4/3/4.html>>.
- Carbonara, N. and Giannoccaro, I. (2011). "Interpreting the role of proximity on Industrial District competitiveness using a complexity science-based view and System Dynamics simulation". *Journal of Geographical Systems*, no.13, pp.415-36.
- Dawid, H. (2006). "Agent-Based Model of Innovation and Technological Change". In Leigh Testfatsion, Kenneth L. Judd (Eds). *Handbook of Computational Economics*. vol.2, Elsevier, pp.1235-72.
- European Commission (2008). "Think small first: A Small Business Act for Europe", DG Enterprise, Brussels, Belgium.
- Giardini, F., Di Tosto G. and Conte, R. (2008). "A model for simulating reputation dynamics in industrial districts". *Simulation Modelling Practice and Theory*, no.16, pp.231-41.
- Iandolfi, L., Ponsiglione, C., Marchione, E. and Zollo, G. (2012). "Knowledge exchange processes in industrial districts and the emergence of networks". *Central European Journal of Operation Research*, no.20, pp.231-50.
- Kiesling, E., Günther, M., Stummer, C. and Wakolbinger, L. (2012). "Agent-based simulation of innovation diffusion: a review". *Central European Journal of Operation Research*, no.20, pp.183-230.
- Martínez-Fernández, M.T., Capó-Vicedo, J. and Vallet-Bellmunt, T. (2012). "The present state of research into industrial cluster and districts. Content analysis of material published in 1997-2006". *European Planning Studies*, vol.20, no.2, pp.281-304.
- 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* vol.5, no.1, <<http://jasss.soc.surrey.ac.uk/5/1/1.html>>.
- Wooldridge, M. and N.R. Jennings (1995). "Intelligent agents: theory and practice". *Knowledge Engineering Review*, no.10: pp.115-52.
- Yahya, S. and Goh, W.K. (2002). "Managing human resources toward achieving knowledge management", *Journal of Knowledge Management*, vol.6, no.5, pp.457-68.