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An agent-based model of firm location with different regional policies

Federico Pablo-Martí
Complex Systems Research Group, University of Alcala, Plaza de la Victoria 2, 28802, Alcalá de Henares, Madrid, Spain
Email: federico.pablo@uah.es

Carlos Muñoz-Yebra
Economics Department, University of Alcala, Plaza de la Victoria 2, 28802, Alcalá de Henares, Madrid, Spain
Email: carlos.munoz@uah.es

Juan Luis Santos
Institute for Economics and Social Analysis (IAES) University of Alcala, Plaza de la Victoria 2, 28802, Alcalá de Henares, Madrid, Spain
Email: luis.santos@uah.es

***Abstract*—This paper presents an agent based model of firm location designed to explore the effect of regional policies on the spatial pattern of business activity. New firms are created each period taking into account the sector profitability and entry barriers. Firms choose their location and then they decide sequentially whether change their size or cease their activity accordingly to the profit maximization principle and the limited information they have. Their costs depend not only on the production level and the price of the productive factors but also on the land price. The characteristics of the territory where the firms are located are not static but rather evolve depending on the public policies, demographic variables and the firm localization patterns. The presented model shows endogenous rules of firm localization as well as the effects in the medium and long term of public policies.**

I. Introduction

Geography and spatial economics have studied in depth the rules of localization of the companies, but many of the complex behaviors that are observed in the reality are still, in great measure, unexplained [1] [2]. Cellular automata and multi agent simulation models constitute new approaches to the problem [3], allow integrating in the models relevant aspects that had not been included in the analysis in quantitative terms due its high complexity.

Multiagent models include agents that interact among each other and with the environment in an independent way. As Huhns and Singh [4] point out these agents consist on small self-contained programs that are able to control their own actions based on their perception of the environment and looking for, in most of the cases, the achievement of certain objectives [5].

Wooldridge and Jennings [6] pointed out some of the characteristics that the agents show and that coincide in great measure with those of the companies:

- Autonomy: Agents act in an independent way not being controlled from the exterior neither their actions neither their internal state while companies enjoy autonomy in their decisions, not being controlled by their competitors.
- Social ability: Agents interact using some kind of language. Companies exchange information by means of their decisions about prices and production.
- Reactivity: Agents as well as companies can perceive their environment and to respond to the stimuli received.
- Proactivity: Both are able not only to react respect the environment but rather they are able to carry out actions for own initiative to this way to reach their objectives.

These coincidences among the characteristics of the agents and those that have the firms make this type of simulations especially appropriate to characterize the behavior of the markets [7].

Cellular automata allow appropriately representing the evolution across the time the spatial variables such as land price and the population [8].

The two dimensions automata cellular models [9] consists on a number of identical cells in a grid provided with a set of variables and behavioral rules. Each cell has a value that can change during the simulation depending on some rules which specify how its next value depends on his actual value and the values of the cell's neighbors of k- dimension [10].

The aggregation of both types of approaches allows studying the behavior of the companies in its localization decisions as well as its effects on the environment. The objective of the paper is to show the main characteristics of this model. The work is structured in two parts: in the first one the structure of the main features of the model are presented and in the second one, an example of its application in a real case is shown, the effect on the localization of firms of the different of policies of two regions in Spain

II. Main features of the model

The agent-based model (ABM) starts with the creation of a number of layers that contain the data of all the firms that potentially can exist in the area. These layers are in many cases cellular automata that determine endogenously the environment variables. Usually the initial values of the exogenous variables proceed of vectorial Geographical Information System (GIS) [11] and they are transcribed into matrixes to be used efficiently in Matlab.

Among the main layers used in the model we can highlight the following ones:

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- Layer1 is a two dimensions matrix (x,y) that represents the territorial aspects that are considered that remain stable in the time such as land height.
- Layer2 is a three dimensions matrix (x,y,t) that shows the time evolution of the main characteristics of the territory. The values of the cells are codes that represent the uses of the land (urban, industrial, services, agriculture, forest, protected area, university technological area).
- Other layers denominated layer3 to layer7 contain the evolution of several spatial variables in the time such as infrastructures, highways, population, railroads, density of firms, etc.
- Other important layers collect the evolution of the land price and the political division of the territory, allowing the introduction of regional policies in the system. Land price is an endogenous variable and it depends among other factors on the localization of companies.

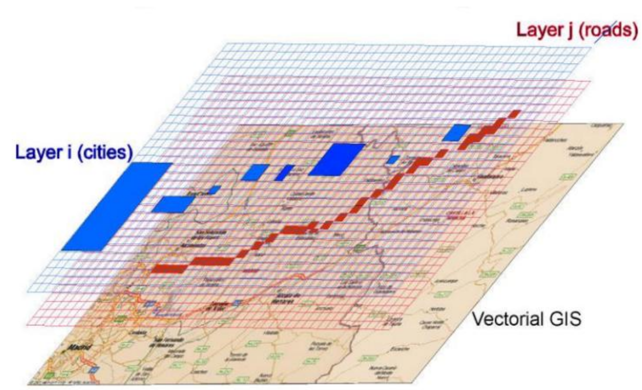

Fig 1. Generation of layers

There are two main approaches to implement the settlement of the agents in the cells: in the first one each cell is occupied by a single agent, in the other one the cells can be shared. Both approaches have advantages and drawbacks. The first option allows monitoring the general behavior of the model; however it seems not realistic when the size of the cells is not small. On the contrary, when the cells can be shared some important aspects of the model can be hidden when the agents cluster in few cells. It is more convenient to use models where agents don't share cells in theoretical studies while better empirical results are obtained when cells are shared. The spatial ABM we present allows both possibilities.

The search system used by firm to find the most convenient location is chosen among these three types: the first one, consist on looking for the place that offers the highest potential profit in the whole area; the second is looking for the place that has the best conditions between a reduced number of possible localizations chosen randomly. Lastly the third type consists on a limited searching in the neighborhood of a random emplacement. The first method is not realistic because the real estate information costs mainly in terms of time devotion [12].

Every company can leave a place when it closes down or if it decides to be relocated. In the first case, the firm is expelled of the market when their profitability is low while in the second one it changes the place although it is profitable if it considers that the derived benefits of the localization change overcome to the costs.

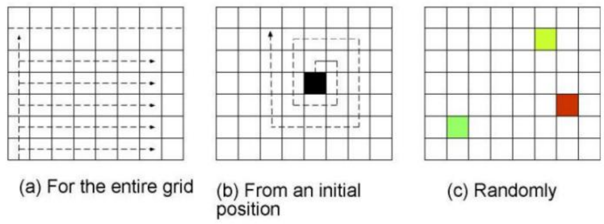

Fig 2. Search mechanisms

From the point of view of the firm mobility it is an evolutionary model that shows the dynamics of populations on the long term allowing the representation of different interrelated sectors. The behavior and the number of firms that exist in each sector are endogenously determined by the model.

Two types of firms are considered in the model: on the one hand the firms originally established in the area and, on the other one, the new ones. This division of the firms in two groups has been made to see as the population of firms evolves from the original situation.

The maximum production capacity of the originally established firms is distributed according to a lognormal function. This hypothesis on the distribution of the production is based on wide evidence that shows a marked asymmetry in the distribution of market shares of the firms [13]. The capacities of the new firms also follow lognormal distributions similar to that of the established companies.

The number of entries in each sector depends on two types of variables. On the one hand, those that have a high level of attraction for the new firms; on the other hand, those that suppose barriers to the entrance.

The barriers to the entrance included in the model are two: the average size of the existing firms in the previous period, as proxy of the existing economies of scale [14], and an exogenous vector of other entry barriers that include the land price. This vector allows the inclusion in the model of institutional changes or external interferences that affect the entrances, making them easier or preventing them.

Firms are able to change their size in each period, sometimes in a voluntary way to adapt to the characteristics of the market, and others because of their financial restrictions. The size is settled as a function of the size in the previous period in order to include the two main theories of firm growth: the stochastic one [15] and the deterministic one[16] (*alpha parameter)*

$$q_{it} = \alpha\left(q_{it-1}\left(1+\frac{N(0,1)}{\tau}\right)\right) + (1-\alpha)\left(q_{it-1}\left(1+\lambda\frac{q_{opt}-q_{it-1}}{q_{it-1}}\right)\right) \quad (1)$$

The available technologies are the same for all the companies of each group. So there is only one cost function for each firm that determines its average costs in function of its production level and its location. This decision has been adopted in order to highlight the central object of the analysis: the localization decision in response to regional policies and market factors.

Firms estimate rationally each period the global market supply in order to decide its own production level to maximize the profits. Firms observe the current price and supply levels to determine their production for the following period and they estimate the future supply of their competitors in function of their own experience, assuming that they will maintain their recent behavior [17].

Although the profitability does not necessarily assure the continuity of the firm, the probability of being expelled of the market is higher when the margin decreases [18]. This relationship is not linear since from certain level of profitability a significant increase in the survival possibility does not take place. However, the reduction of the margin below a critical level represents a significant increase in the probability of closing down [19]. A good location reduces the costs and improves the margins, promoting the firm success.

The coexistence of firms with different dimensions and, therefore, with different costs, means that, for a certain level of prices, firms with high probabilities of survival and others with practically none can exist at the same time. And as the margins of each firm depend on the price, the exits are affected indirectly by all the variables that affect this: demand, production levels, imports and entrances.

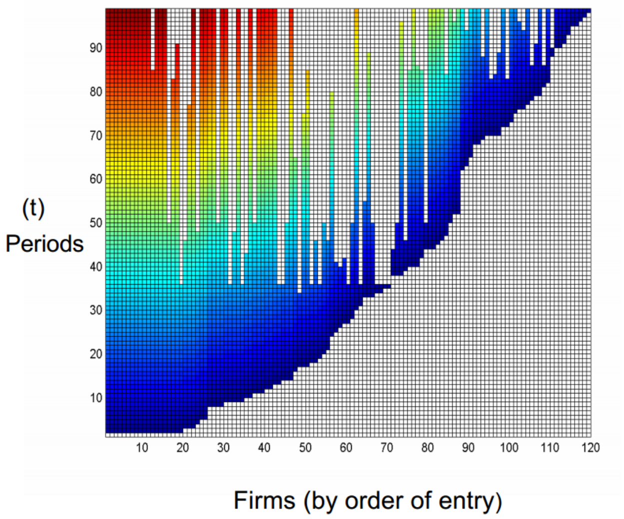

Fig 3. Firm demography

The non-linearity is observed in the Bernouilli function for the survival probability of the firm B(p). p is a logistic function that depends on the Lerner index for each sector:

$$p = \frac{1}{1 + e^{-\frac{IL_i - \alpha}{\beta}}} \quad (2)$$

The demand functions are linear and are assumed to remain stable during the simulation to focus the study on firms' decisions without external demand shocks. Demand equation for firms created before t=0 is

$$P_{nt} = a_1 - a_2\ Q_{nt} - a_3\ Q_{et} \quad (3)$$

Demand equation for new firms:

$$P_{et} = b_1 - b_2\ Q_{nt} - b_3\ Q_{et} \quad (4)$$

Where P_{nt} is the price charged in time t, Q_n the aggregated production level, Q_e the production of the entrants. n and e make reference to initial firms and entrants respectively.

Demand functions conditioned by production factors are defined as:

$$k_t(w_t, r_t, q_{it}) = A^{-\frac{1}{a+b}} \left[\frac{a\ r}{b\ w}\right]^{\frac{b}{a+b}} q_{it}^{\frac{1}{a+b}} \quad (5)$$

$$l_t(w_t, r_t, q_{it}) = A^{-\frac{1}{a+b}} \left[\frac{a\ r}{b\ w}\right]^{-\frac{a}{a+b}} q_{it}^{\frac{1}{a+b}} \quad (6)$$

Then, the forecasted market supply is:

$$E(Q_{nt}) = \bar{Q}_{nt} + h_1(p_{n,t-1} - \bar{p}_{nt}) + h_2(Q_{n,t-1} - \bar{Q}_{nt}) \quad (7)$$

$$E(Q_{et}) = \bar{Q}_{et} + h_3(p_{e,t-1} - \bar{p}_{et}) + h_4(Q_{e,t-1} - \bar{Q}_{et}) \quad (8)$$

For initial firms and entrants respectively. Where mobile averages of the last k periods are computed; *h1* and *h3* are the response coefficients to price variations; *h2* and *h4* are the ones to quantity changes.

The estimated production for the established firm i and for its established competitors, Q^*ni, is the market forecast for the group of firms:

$$E(Q^*_{nit}) = E(Q_{nit}) - E(q_{nit}) \quad (9)$$

The production that the market expects for each of the established companies is similar to that of market as a whole:

$$E(q_{nit}) = \bar{q}_{nit} + h_{i1}(p_{n,t-1} - \bar{p}_{nt}) + h_{i2}(q_{ni,t-1} - \bar{q}_{nit}) \quad (10)$$

It is computed each period after the total production computation. Thus, the profit function to optimize is:

$$\Pi_{nit} = p_{nt}(Q^*_{nit}, Q_{et}, q_{nit,})q_{nit} - c_n(q_{nit}) \quad (11)$$

And the optimal production level for the established firms is expressed as:

$$q_{nit} == \frac{\frac{\partial c_n(q_{nit})}{\partial q_{nit}} - p_{nt}(Q^*_{nit}, Q_{et}, q_{nit,})}{\frac{\partial p_{nt}(Q^*_{nit}, Q_{et}, q_{nit,})}{\partial q_{nit}}} \quad (12)$$

In the same way, the optimal production for entrants is:

$$q_{eit} == \frac{\frac{\partial c_{et}(q_{ejt})}{\partial q_{ejt}} - p_{et}(Q^*_{ejt}, Q_{nt}, q_{ejt,})}{\frac{\partial p_{et}(Q^*_{ejt}, Q_{nt}, q_{ejt,})}{\partial q_{ejt}}} \quad (13)$$

The expected profits coincide with the margin that each group of companies has earned in the previous period, defining these ones as the difference between the sales price and the average of the marginal cost of the companies in the group.

$$E\pi_{nit} = IL_{nt-1} = \frac{P_{nt-1} - \left(\sum CMg_{nt-1} \big/ N_{t-1} \right)}{P_{nt-1}} \qquad (14)$$

$$E\pi_{eit} = IL_{et-1} = \frac{P_{et-1} - \left(\sum CMg_{et-1} \big/ E_{t-1} \right)}{P_{et-1}} \qquad (15)$$

where N_t and E_t are the number of established firms and entrants in each period and CMg_t are the marginal cost of each company.

III. Model Application

The model is applied an industrial area called *Corredor del Henares* (CdH) that has more than 600,000 inhabitants and is one of the biggest industrial area in the south of Europe. It is divided into two regions where different policies are applied. The area can be seen as a continuum of urban and industrial areas in the proximity of the European route E90, one of the nine west-east references routes of the continent.

Before starting the description of CdH, it is convenient to make a brief reference the Madrid Region that, located in the geographical center of the Iberian Peninsula, constitutes the central node of terrestrial and air communications of the country and the most important administrative and economic center. The industrial and demographic growth in Madrid environment has been articulated around a radial net of roads that communicate the capital of Spain with the rest of the national territory.

Madrid Madrid (with near 850 inhabitants/Km^2) presents the highest population density of Spain, comparable to other developed European regions. The mean population's density is higher by the main municipalities of CdH and it arrives until near 8,000 inhabitants/Km^2 in the case of the municipality of Coslada. It is denominated *Corredor del Henares* to the land fringe of approximately 60 Km of longitude that extends from the oriental border of Madrid city until the city of Guadalajara, settling on the whole on the valley of the Henares river and a traverse tract of the Jarama valley.

Fig 4. Region under study (CdH)

The fertile and flat land favored the consolidation of the towns and the development of the road network that have been historically a main piece in the economic and social articulation of the area.

The most important municipality in the area under study is Alcalá de Henares, so much for its size and recent development, like for its history. It is located in the center of CdH between Madrid and Guadalajara.

The cities of this area have developed around the highway and the railroad that connect Madrid with Barcelona and the rest of Europe.

In CdH there can be distinguished two well differentiated areas:

A. - The one that we could denominate as "recovered industrial area in decline" that includes the area to the east of the city of Madrid until Alcalá of Henares. It is the area that has experienced a bigger economic and demographic development. This area is in Madrid region, traditionally it has a high level of economic activity and occupation; due to the scarcity of industrial land in the region.

Regional public support to firms is limited by the regional policies of the EU, although the high unemployement is reverting the scarcity of public funding in this area.

B. - The one that we could denominate as "recently industrialized area" embraces the territory to the east of Alcalá of Henares until the city of Guadalajara. It includes the municipalities of Azuqueca de Henares, Alovera, Cabanillas del Campo, Marchamalo and Guadalajara, all of them belonging to the region of Guadalajara that is part of Castille-La Mancha and on the contrary that in the Madrid side of the Corridor it has a lot of cheap industrial land. The industrialization in this area has happened later and it seems to have been due at least partially to the different subsidies to the industrial investment in comparison to the ones offered by the neighboring Madrid region.

The industrial growth of CdH began during the decade of the sixties and it affected mainly the municipality of Coslada (the nearest to Madrid), also extending along the E90 highway to the municipalities of San Fernando, Torrejón and Alcalá. During the last five years the industrial and demographic growth has extended in a double way:

On the one hand, a diffusion of the industrialization process toward other municipalities of Madrid region adjacent to the central axis of the Corridor (among other we can highlight Mejorada del Campo, Paracuellos del Jarama, Ajalvir, Torres de la Alameda and Daganzo de Arriba). In this case, normally they are companies of small size that are attracted by the lower prices of the land in these municipalities. The improvements in the infrastructures and the new roads that communicate this location with E90 and other main highways also play an important role in the development of these towns.

On the other hand, it has been a development toward the East following the E90 and the railroad until the city of Guadalajara [20]. A remarkable process of industrial localization of firms has taken place. In many cases these companies were previously located in other places of Madrid region or, even, in other distant regions.

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The firms have been attracted to this area mainly by the availability of industrial land next to the E90 highway, well communicated and not too far from Madrid. The lower prices of the land and the higher public funding to the industrial investment have constituted twp crucial variables in the localization process in this area.

In this work the questions related with the land offer and the managerial mobility are also approached, contemplating the land supply, as a factor that conditions the entrance of new companies, and as a determinant of the disappearance of industrial establishments expelled by the possibility of obtaining high profits due to considerable real state appreciations.

As complete information for the environment variables were not available they were approaches by means of mathematical functions.

The figure 5 shows the distribution of the localization advantages for the firms where is possible to observe the influence of the transportation costs and the proximity to the markets.

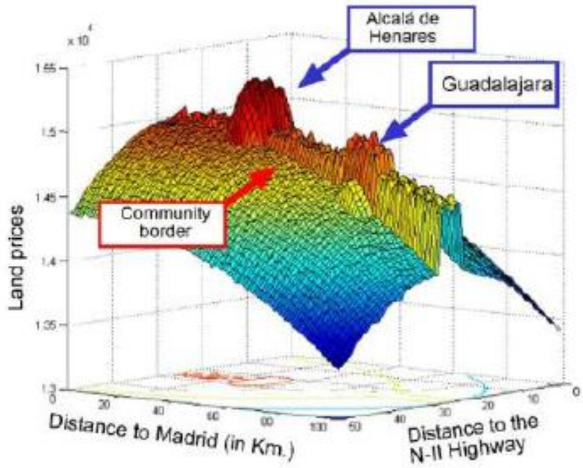

Fig 5. Location utility without policy impact

It can be appreciated that the land price is considerably higher around the E90 highway, and around the main urban areas, Alcalá and Guadalajara. The figures also reveals the localization advantages and the land price are not distributed in a uniform way. There are places where the advantages and the price of the land are considerably different from their nearer environment.

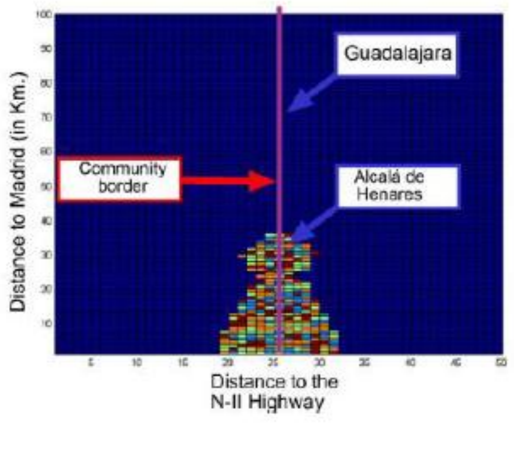

Fig 6. Business location without policy impact

This aspect has considerable importance since it allows the random emergence of groups of companies around points that have some advantages in comparison with neat places. These points can be the seed for the emergence of clusters.

The result of the simulation with this data (figure 6) shows how the companies are located around the E90 highway marked in purple in the nearest area to Madrid until Alcalá. The nearer to Madrid the bigger the industrial area is. No one firm is located in the less populated region although the land price is lower. This result opposes the actual business location pattern observed in Figure 7, with the majority of firms near Madrid and also in Alcalá de Henares, but some of them in Castille-la Mancha near the border between the two region and other ones in Guadlajara.

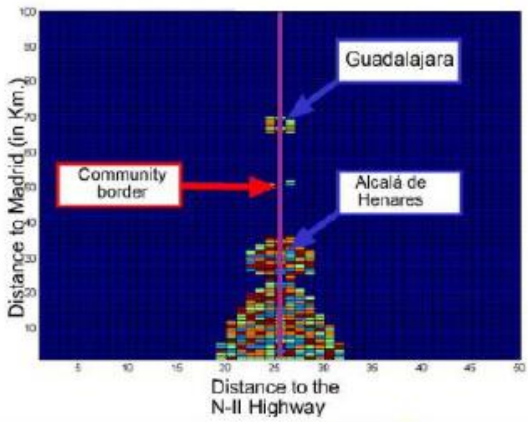

Fig 7. Actual business location

The difference between the result of the simulation and the actual pattern can have two origins. The first possibility is historic reasons, but in that case we would observe a declining industry in Castille-la Mancha and the opposite dynamics is observed in the last two decades. Then the difference between the simulation result and the actual behavior must be the different policy of the regional governments of these two regions. In fact Madrid is more concerned about environment and Castille-la Mancha tries to attract new companies with low tax policies and less regulation [20]. Our objective is to show how these policies affect the costs of companies and we can represent the policy impact as a grant to new plants.

To check if the lack of accuracy of the model was due to the existence of public helps to the localization of companies in Castilla – La Mancha a variable step it was introduced in the price of the land lowering the level of the price in all the cells corresponding to this community (figure 8). The following simulations showed a similar results to the reality.

In this case, a significant part of the companies is located to the other side of the border between the two regions, being created two clusters of firms, one just in the border near to Azuqueca and other bigger in Guadalajara.

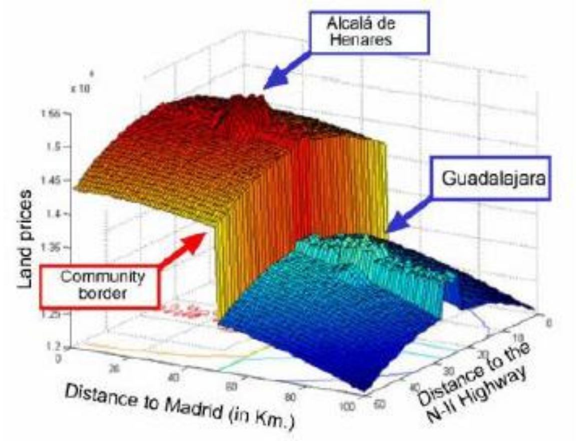

Fig 8. Location utility with the policy impact

One of the most outstanding results is that the politicians of incentives, when they don't suppose improvements in the efficiency of the company, they give changes as a result in the space distribution motivated by the competitive distortions that can generate (deviation effect) more than the number of companies located in the group of the considered geographical area to increase (creation effect).

IV. Conclusions

In this paper we present an ABM that allows measuring and visualizing the spatial patterns of business activity and forecast its dynamics under the current or different public policy scenarios. We check the validity of the model with an industrial area divided into two regions with different policies.

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