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Driade Space: An agent based simulation model for the analysis of the firm demography and the localization patterns in urban areas

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Abstract

An agent based model of firm mobility is presented in which diverse types of firms decide their geographical localization in function of some spatial variables.

The Driade Space model considers the demography of firms in a wide sense: number of firms, entries and exits, distribution of sizes as well as the spatial density of firms. The number of firms in each market is function of the profitability observed in the sector in the previous period and the height of the entry barriers. The companies are rational and they act on the variables in function of their objectives and of the limited information they have on the evolution of the market and the behavior of their competitors. This way, the companies in the moment of their entrance decide the localization they expect that will be more profitable considering their own characteristics while in the successive periods they decide on their investments and their production.

The costs of the companies depend not only on the production level and on the price of the used productive factors but also on the price of the land. The derived economies of the initial decision of localization are also considered. The characteristics of the territory where the firms are located are not static but rather evolve depending on the applied policies, demographic variables and the localization of the firms.

The model presented allows showing the endogenous rules of firm localization as well as the effects in the medium and the long term of the public policies.

1. INTRODUCTION[1]

Although as much the regional economics as the geography have studied in depth the rules of localization of the companies, many of the complex behaviors that are observed in the reality are still, in great measure, unexplained. The cellular automata and multi agent simulation models constitute news approaches to the problem, when allowing integrating in the models relevant aspects that had not been able to be included in the analysis more than in qualitative terms due its high complexity.

The multiagents models are constituted by agents that interact to each other and with the environment in an independent way. As Huhns and Singht point out (1998) these agents consist in small self-contained programs that are able to control their own actions being based on their perception of the environment looking for, in most of the cases, the achievement of certain objectives (Gilbert and Troitzsch, 1999).

Wooldridge and Jennings (1995) pointed out some of the characteristics that the agents show and that they coincide in great measure with those of the companies:

Autonomy: The agents act in an independent way not being controlled from the exterior neither their actions neither their internal state while the companies enjoy autonomy in their decisions, not being controlled by their competitors

Social ability: The agents interact using some kind of language. The companies exchange information by means of their decisions about prices and production.

Reactivity: The agents as the companies can to perceive their environment and to respond to the received stimuli.

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.

[1] This research is supported by a grant of the Plan Nacional de I+D+I of the Ministerio de Ciencia y Tecnología reference SEC-2000-0882-C02-01

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

The cellular automata allow appropriately representing the evolution in the time of the spatial variables as the price of the land or the population.

The two dimensions automata cellular models consists of a number of identical cells arranged in a rectangular array. Each cell has a value that can change when the time advance depending of some rules which specify how his next value depends on his actual value and the values of the cell's immediate neighbours.

The conjunction of both types of models allows studying the behaviour of the companies in its localization decisions as well as its effects on the environment. The main objective of the paper is to show the operation and main characteristics of the model Driade Space of firm demography developed in the Laboratory of Computational Finances. The work is structured in two parts: in the first one the structure of the model is presented; in the second one, an example of its application in a real case is shown, the influence on the localization of firms of the differences of incentives between two provinces in Spain.

2. THE MODEL

When the model was developed it was tried to endow him of a wide degree of flexibility that allowed picking up a broad variety of situations. It is formed by several modules that it allowed adapting to analysis necessities without to carry out a deep modification of the model.

The modules are contained in two groups: The first one collect the aspects relates with the localization of the companies using a cellular automata methodology, while the second one is centered fundamentally in the firm demography and uses mainly an agent based approach.

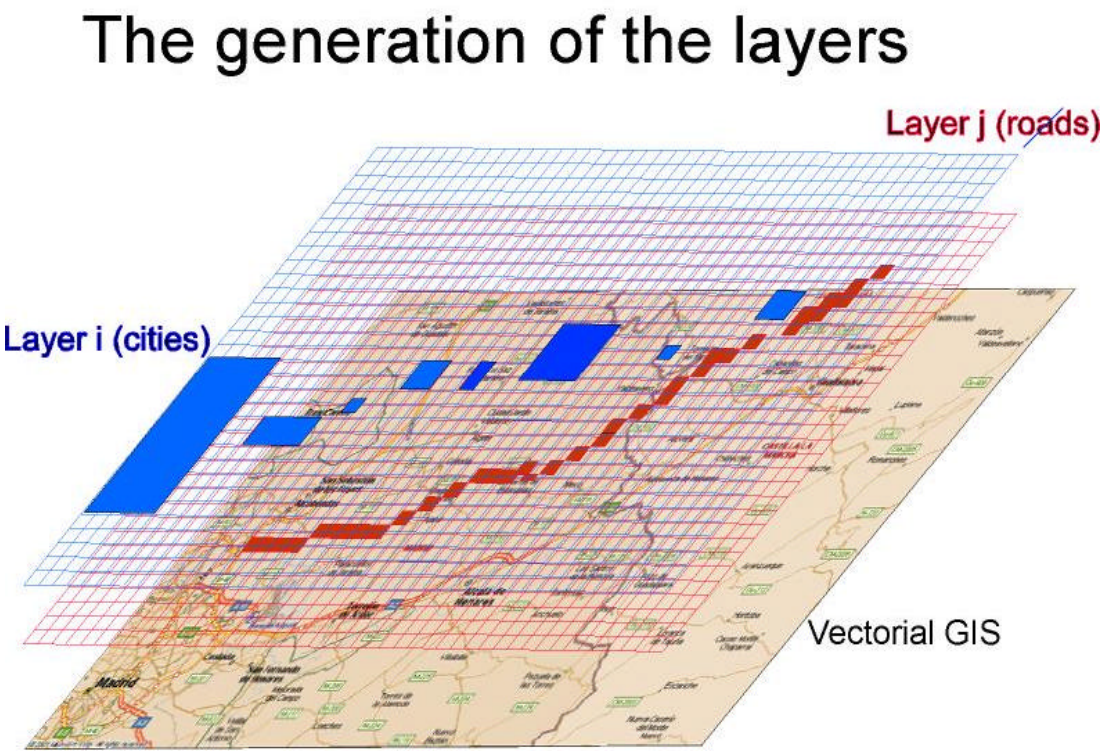
The localization of firms

The model starts to create several matrixes that will reflect the data of all the firms that potentially can exist in the area. These matrixes 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 systems and they are transcribed to matrixes (figure 1). This transformation requires choosing the size of the cells that will be represented by the elements of the matrix.

When the initial data are available then they are introduced directly in model, in other case is carried out some approach type.

Figure 1



Among the main matrixes or layers, used in the model we can highlight some ones:

? *Layer1* is a two dimensions matrix (x,y) that it represents the territorial aspects that are considered that remain stable in the time, how the geographical accidents for example.

- *Layer2* is a three dimensions matrix (x,y,time) that shows the evolution in the time of the main characteristics of the territory. The values of the cells are codes that represent the uses of the land
  - 1. - urban area
  - 2. - industrial area
  - 3. - services area
  - 4. - agricultural area
  - 5. - forest area
  - 6. - natural park or protected area
  - 7. – university or technological center

Other matrixes with the same characteristics that *layer1*, denominated *layer3* to *layer7* picks up the evolution of several spatial variables in the time such as infrastructures, highways, population, railroads, density of firms, etc.

Other important matrixes are *C_land* and *municipalities* that collects respectively the evolution of the price of the land and the political division of the territory, what allows the valuation of regional policies. The price of the land is an endogenous variable and it will depend between other things on the localization of companies.

When the new companies choose their places also consider the density as a relevant variables in function of their own characteristics. In general, the agglomeration of firms be an element of attraction for the new companies until the saturation of the infrastructures they begin to become a negative aspect.

There are two main approaches on the implementation of the settlement of the agents in the cells: in the first one each cell is occupies for only an agent, in the other the cells can be shared. Both approaches have advantages and inconveniences. The consideration that the agents cannot share cells has the advantage that allows observing clearly the general behaviors of the model, however it seems not very realistic in many cases, especially when the size of the cells are not extremely small. On the contrary, the consideration that the cells can be shared although more realistic when the cells are big has the inconvenience that it can hide important aspects of the model when the agents concentrate in some few cells.

This way, seems more convenient to use models where the agents don't share cells in theoretical studies while it will be better the use of models in those that the cells are shared in the applied ones. The Driade Space model allows the consideration of both possibilities. The variable of firm density allows controlling the establishment of companies in a certain place. This variable picks up the number and type of companies that it exists in each moment in a concrete cell by means of an algorithm.

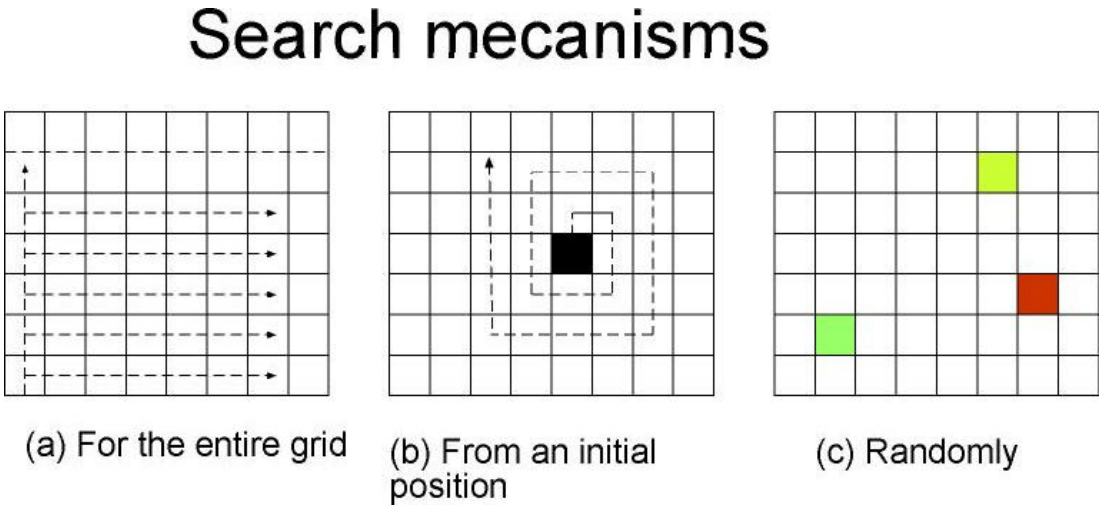
The variable *V_land* picks up the valuation made by each firm of the space (including the density of firms) in function of the sector that belongs and of its own characteristics. This variable together with *C_land* will determine which are the elected localizations for the firms in each moment.

Finally, *Locagent* is a 5 dimensions matrix (sector,firm,time,x,y) that shows each agent's geographical localization in each moment of the time. This matrix store the location of the companies allowing to know the changes.

When the companies birth choose the best place for their establishment in function of their own characteristics, sector to which they belong and their size valuing for each cell the different relevant variables. The search system that they use to find the appropriate location can be of three types: the first one, consist on looking for the place that offers bigger advantages in the whole area; the second, looking for the place that offers better conditions between a reduced number of possible localizations chosen randomly. Lastly the third type way of search consists in that when the companies change their locations choose a place near to their original emplacement (figure 2).

The election of the system depends basically of the search costs. Although a priori the first system seems better, in the practice it can be more efficient an incomplete search as the others two cases, given the imperfect information in the real state market. These incomplete forms of search have a wide support especially in the managerial literature in the case of the small companies. The managers establish their companies in the well-known environment where they develop their activity.

Figure 2



Source: Otter, der Veen and de Vriend (2001) and own elaboration.

The causes for those that a company can leave a place are mainly two: because leaves the market completely or because 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 could abandon the place although it is profitable if considers that the derived benefits of the localization change overcome to the costs. In the model it is only considered the changes of localization taken place in a next environment, not being included the international relocations that are due to variations in the competitive advantage of the nations. This way, the firms value each period the opportunity costs tied to their localization and consider if the benefits that would have for the sale of their place overcome to the costs of the localization change. This way, the companies consider the value of the land that they occupy and the costs of the transfer, defined both as a percentage of the total value of the assets of the company and they compare it with the benefits of the new localization.

Firm demography

From the point of view of the firm mobility it is an evolutionary model that shows the evolution of populations on the long term allowing the representation of different sectors that can be interrelated. The behavior and the number of firms that exist in each sector are endogenously determined for 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, 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 firms' capacity of production 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 indicates a marked asymmetry in the distribution of market shares of the firms. 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 which suppose a higher 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, and an exogenous vector of other entry barriers that include the cost of the land. This vector allows the inclusion in the model of institutional changes or external interferences that affect the entrances, favoring them or impeding them.

The firms do not remain unaltered in the markets but they vary their size, sometimes in a voluntary way to adapt to the characteristics of the market, and others forced by the circumstances. To integrate in the model this dynamic aspect, the size in each period is settled as a function of the size in the previous moment. It was pretended to make this function sufficiently flexible in order to be able to pick up the two main theories of the firm growth: the stochastic one and the deterministic one.

It is considered that 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. It is maybe an excessive simplification but it has been adopted in order to make clearer the central object of the analysis.

Due to the lack of information of the firms about the real behavior of their competitors, consider that they behave the same way as the market at a whole. The firms estimate rationally each period the global market supply in order to decide its own production level that maximizes its benefits. The model considers that the firms observe the current levels of price and supply to determine their production for the following period and that they estimate the future supply of their competitors in function of their own experience, supposing that they will maintain their more recent behavior.

Although the profitability does not necessarily assure the survival of the firm, the probabilities of being expelled of the market are bigger when the margin are narrows. This relationship is not lineal since from certain levels of profitability a significant increase in the survival possibilities does not take place; however, the reductions of the margins below a critical level, although small, suppose a significant increase of the probabilities of exit. A good location reduces the costs and improves the margins favoring the survival. The external economies bounded to the firm density also influence in the possibilities of remain in the market.

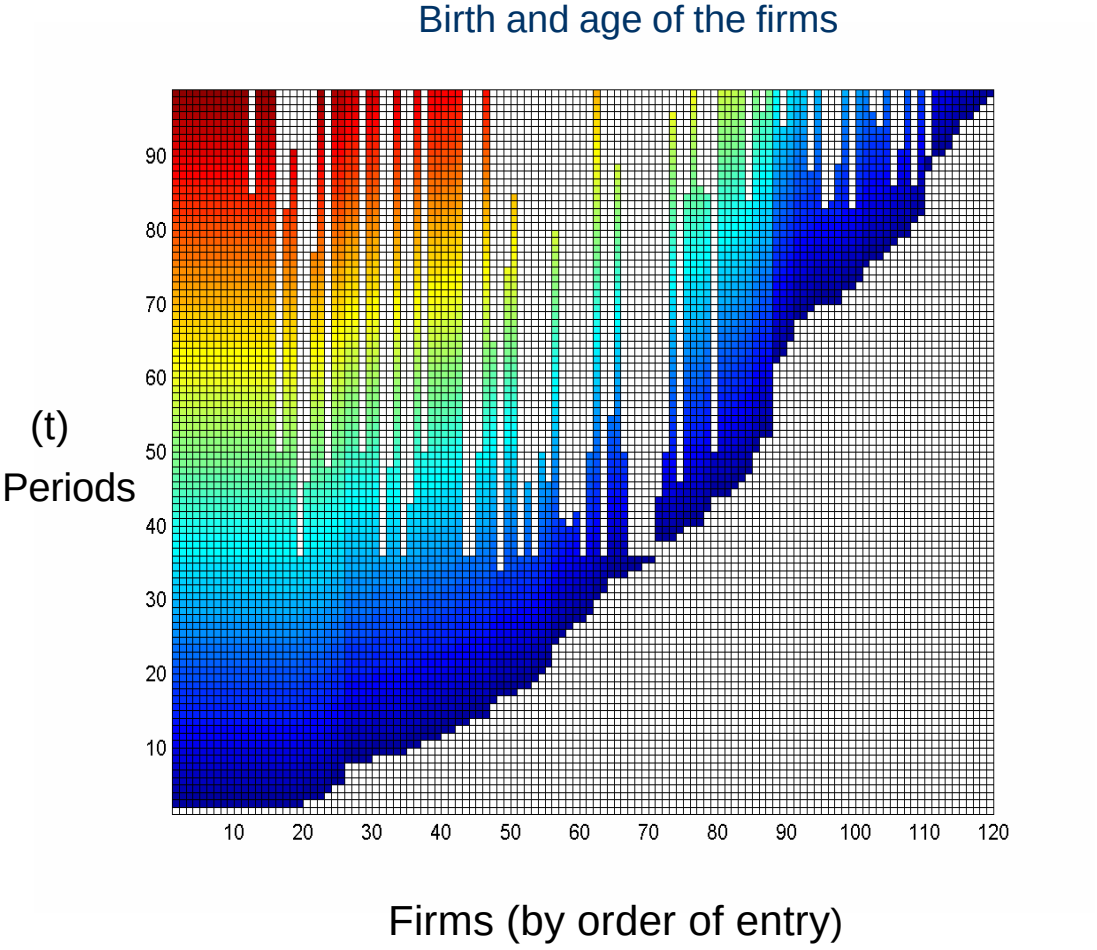
The coexistence of firms with different dimensions and, therefore, with different costs, means that, for a certain level of prices, firms with high probabilities of survival and others with practically none can exist at the same time. And as the margins of each firm depend on the price, the exits are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

The used demand functions are lineal and are supposed to remain stable during the simulation. Although the introduction of demand functions that evolve with the degree of maturity of the market is simple, it was considered that it was preferable to analyze the behavior of the population of firms for reasons exclusively deriving from the firms mobility.

In the figure 3 the evolution of population of firms is showed.

Figure 3

Birth and age of the firms



3. AN APPLICATION EXAMPLE: THE FRONTIER EFFECT IN THE HENARES CORRIDOR

Next we will use a case of regional analysis to show the applicability of the model. The objective of the study is to show the used methodology applying it to a real case observed in Spain. In this occasion, the cells have a size of a square kilometer and in order to showing the general outlines of the model are not allowed to be share by the agents.

The policies of regional development applied traditionally in Spain have experienced considerable changes after the integration in the European Union. One of the questions more debated from the political point of view is the possibility of the emergence of the

frontier effect due to the differences in the regional incentives for the localization of firms.

Using the Driade model, It is studied the demography of the companies along the Henares Corridor in function of the evolution of the prices of the land, the endowment of infrastructures, demographic variables and public incentives to the investment. That area groups the populations located around the highway N-II in the tract between the cities of Madrid and Guadalajara.

In this sense it is tried to gauge the incidence in the long term of the important differences of public incentives to the investment and costs of the land among adjacent territories.

The Henares Corridor

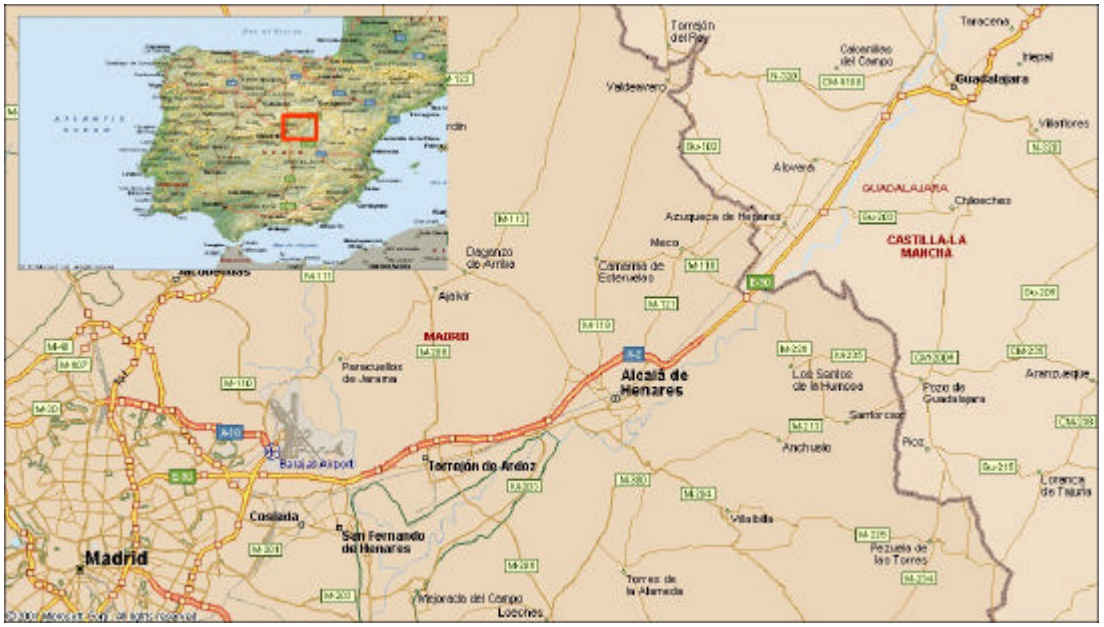
Before carrying out a description of the Henares Corridor, it is convenient to make a brief reference the Community of Madrid that, located in the geographical center of the Iberian Peninsula, constitutes the central node of terrestrial and air communications of the country and the most important administrative 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.

The Community of Madrid (with near 700 inhabitants/Km2) it presents the highest density in population from Spain, comparable to other very developed European regions. The mean population's density is very overcome by the main municipalities of the Henares Corridor and it arrives until near 7.000 inhabitants /Km2 in the case of the municipality of Coslada.

It is denominated Henares Corridor 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 (figure 4).

Figure 4

The Henares Corridor



The fertile and flat land favored the consolidation of the towns and the development of the roads that have been historically key piece in the economic and social articulation of the Henares Corridor.

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

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

In the Corridor two well differentiated areas can be distinguished.

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 that it is the area that has experienced a bigger economic and demographic development. This area is in the Community of Madrid, with a high level of economic activity and occupation; due to the scarcity of industrial land the costs to locate firms are high. The public supports to the firms are quite limited for the

Regional Policies of the EU (although the municipalities of San Fernando de Henares, Torrejón de Ardoz and Alcalá de Henares are region objective 2).

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, Cavanillas del Campo, Marchamalo y Guadalajara all belonging to the province of Guadalajara that is part of the Community of Castilla-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 been later and it seems to have been due at least partially to the different subsidies to the industrial investment (this area is region objective nº1) regarding the offered by the neighboring Community of Madrid.

The industrial growth of the Corridor began during the economic development of the decade of the years sixty and it affected mainly to the municipality of Coslada (the nearest to Madrid), also extending along the N-II 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 one hand, a diffusion of the industrialization process toward other municipalities of the Community of Madrid adjacent to the central axis of the Corridor (among other we can highlight Mejorada del Campo, Paracuellos del Jarama, Ajalvir, Torres de la Alameda, 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 with the N-II and other main highways also play an important role in the development of these towns.

On the other hand, the development toward the East, following the N-II and the railroad until the city of Guadalajara has taken place an important process of industrial localization of firms that, in many cases, they were previously in other places of the Community of Madrid or, even, in other distant regions.

The firms have been attracted to this area mainly by the availability of industrial land next to the N-II highway, well communicated and not too far of Madrid. The lower

prices of the land and the bigger public helps to the industrial investment have constituted a crucial variable in the localization process in this area[2].

In this work the questions related with the land offer and the managerial mobility are also approached, contemplating the floor offer, as much as a factor that conditions the entrance of new companies, as a determinant of the disappearance of industrial establishments expelled by the possibility of realization of important real state appreciations.

Implementation of the problem

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. The figure 6 shows the prices of the land for the period one. In him it can be appreciated as the price of the land it is considerably higher around the highway N-II, and around the main urban nuclei, Alcalá and Guadalajara. The figures also sample as the localization advantages and the price of the floor are not distributed in a totally uniform form way. There are places where the advantages and the price of the land is considerably different from their nearer environment. This aspect has considerable importance since it allows the random emergence of groups of companies around points that have some advantages to their environment. These points can be the seed for the appearance of clusters.

[2] A similar phenomenon is observed in the municipalities of the region of Toledo adjacent with the south of the Community of Madrid and well communicated with him. This towns belongs equally to the Community of Castilla - La Mancha and included in the group of regions objective 1 of the European Union.

Figure 5

The *V_land* matrix for a representative firm

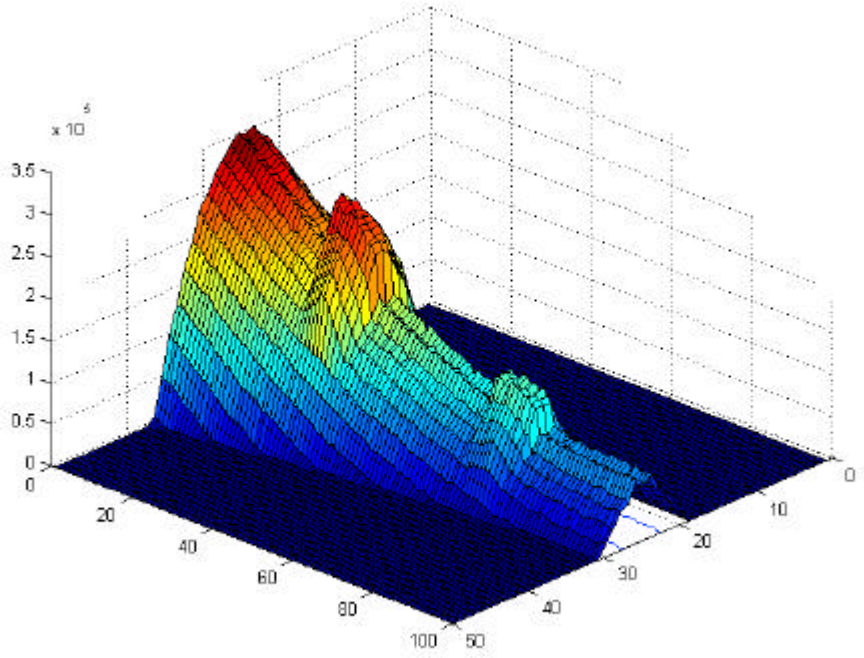


Figure 6

The price of the land in the Henares Corridor
(without regional incentives)

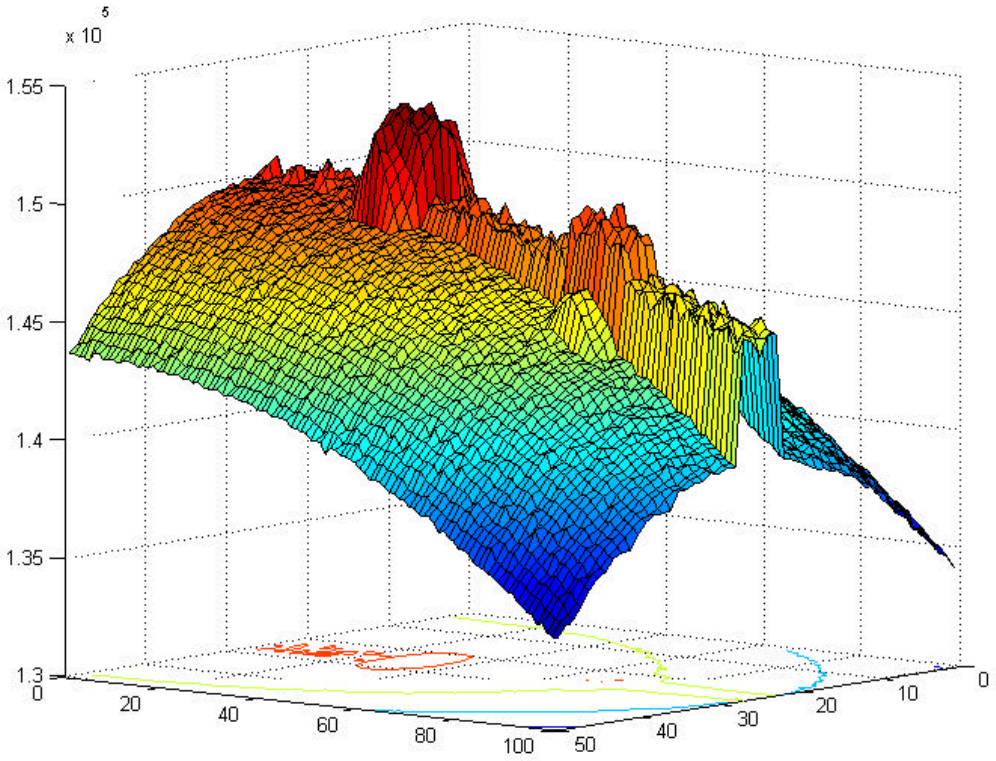
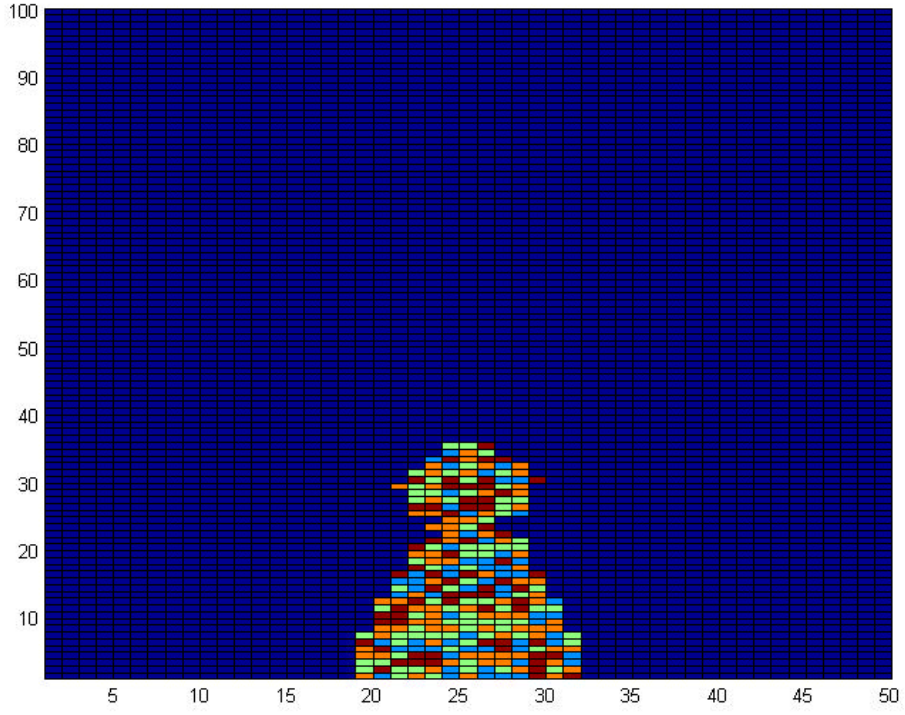


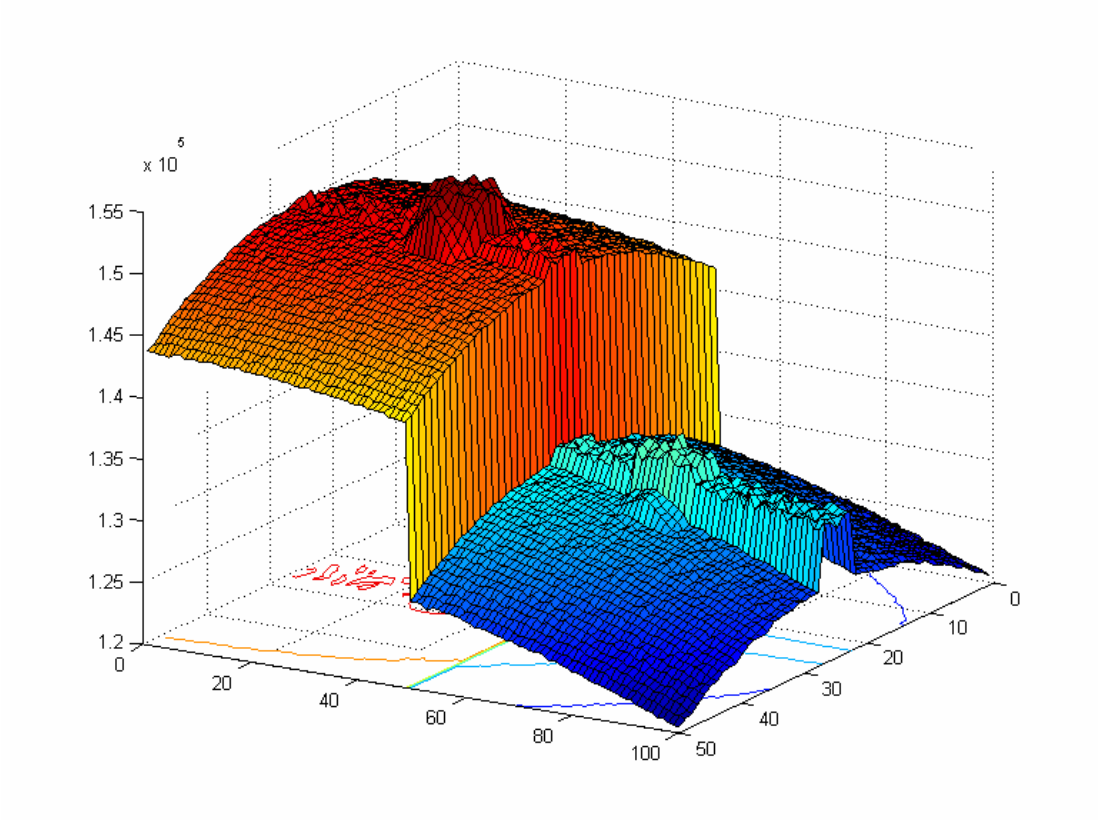
Figure 7
The location of firms in the Henares Corridor
(without regional incentives)



The result of the simulation (figure 7) shows as the companies they are located around the highway N-II in the nearest area at Madrid until Alcalá. The more near to Madrid the width of the industrial area is bigger. Since in this case differences have not been specified in the behavior of the different types of companies and the distribution of the companies by sectors it doesn't show a defined outline.

The obtained results although considerably coincident with the reality they undervaluate the localization of the companies and the part of the Henares Corridor that it is in Castilla-La Mancha

Figure 8
The price of the land in the Henares Corridor
(with regional incentives)

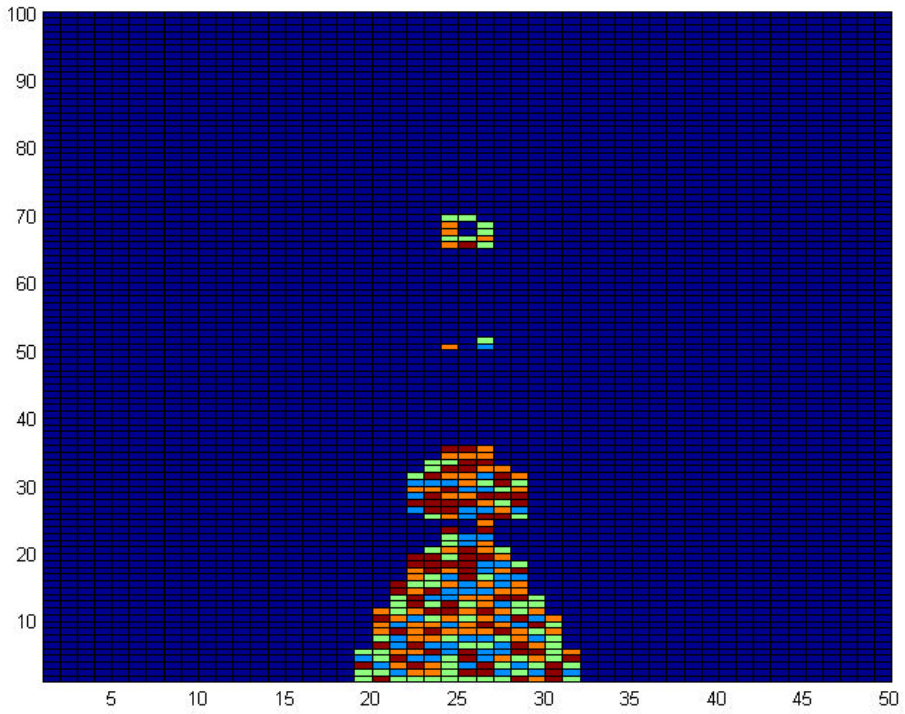


To check if the lack of accuracy of the model was due to the existence of public helps to the localization of companies in Castilla – La Mancha a variable step it was introduced

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 much nearer results to the reality (figure 9).

Figure 9

The location of firms in the Henares Corridor
(with regional incentives)



In this case, a significant part of the companies is located to the other side of the frontier among the two autonomous communities, being created two nuclei of firms, one just in the borde near to Azuqueca and other more important in Guadalajara.

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 (effect creation).

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