

DRÍADE: A DYNAMIC MODEL OF MARKETS SIMULATION

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ABSTRACT

In this paper is presented a multiagent model of long term firm mobility. The firms select their optimal levels of production depending on their expectatives about the market and their competitors' actions.

The market consists on two kinds of firms: the ones already present in the market and the new ones. Both types compete in interrelated markets in which the products are imperfect substitutes. The size of the firms varies depending on the mean return in the market as well as random effects while the entry of new firms depend on the margin.

INTRODUCTION

The behaviour of the firms in the markets shows several aspects making it therefore especially appropriate for the use of agent based methodology since the basic characteristics of autonomy, social ability, reactivity and proactivity that define the behaviour of the agents (Wooldridge and Jennings, 1995) are likewise the fundamental elements of the behaviour of the firms.

The firms have autonomy in its decision taking; they are able to act independently not being controlled from outside neither their actions nor their internal state. This characteristic of the firms is difficult to consider from other methodologies different to the agent based simulation without the inclusion of the supposition that all the firms have the same information and behave the same way. However, the modelling at individual level does not only allow to consider heterogeneous firms but also to include aspects so important and hardly considered as the asymmetric information or the imperfect rationality.

On the other hand the firms communicate and interrelate with each other, that means, they have social ability. This communication can be through such

simple language as the production or through subtle signs in the tacit collusion.

Another aspect is that the firms have reactivity and are able to perceive their environment and to respond to the received stimuli acting on the instruments they have as the production level, the investment or the R&D.

Finally, the companies are proactive, they are not only able to react to what happens in their environment but they take their own initiative to reach that way an objective.

In spite of the evident adaptation of the agent based methodology to the study of the evolution of the markets, its use in the industrial economics has been extremely reduced, due, probably, to the scepticism of an important part of researchers who are not expressly formed in computer techniques and therefore for them the computer program code is in great measure opaque (Valente, 1998).

In this paper the DRIADE model of firms mobility developed in the Laboratory of Computational Finances of the University of Alcalá is presented¹. The model seeks to be highly realistic and which makes it therefore compatible with the abundant research carried out from the main approaches to the dynamic of markets: in first place, the wide and often dispersed descriptive literature on the topic (Dunne et al., 1988; Baldwin, 1995); in second place, the literature based on the industry life cycles (Klepper (1996); Afuah and Uterback (1997) and, lastly, the related with the population ecology of organizations (Hannan and Freeman, (1989), Carroll and Hannan (1995).

Although this eclectic perspective has been considered by diverse authors (for example Winter et al., 1998) some new aspects have been introduced in the model that makes it highly flexible allowing the theoretical analysis of the evolution of the markets as well as the representation of a wide variety of real markets with prediction objectives.

¹ This model is a partial development of chapter IV of my doctoral thesis with the title: the firms mobility in the Spanish industry.

Among the innovations of the model can be highlighted the following ones:

In the first place, the entrance of new firms in each period is not fixed nor exclusively random but depends on the evolution of the market. The number of entries is fundamentally determined by the profitability observed in the sector in the previous period and the size of barriers to the entry. These in turn are not static but vary depending on the market maturity.

In second place, the exit of firms does not exclusively depend on their profitability but is also affected by random aspects.

In third place, the costs of the firms are not fixed but are determined by their production level and the price of the production factors 'work and capital' that allows the consideration of economies of scale.

In fourth place, the firms are rational and act on the variables within their reach in function of their objectives and the limited information they have on the evolution of the market and the behaviour of their competitors.

In fifth place, the model allows the existence of sub-markets whose products are imperfect substitutes and where firms of different sizes and levels of efficiency are competing.

In sixth place, the results of the model, as being influenced by random aspects and as they vary from one simulation to the other, are not expressed in absolute terms but as distributions of probability by means of the use of Bootstrap techniques (Efron, 1982; Efron and Tibshirani, 1993)².

Finally, the model has a modules structure which allows to enlarge and modify it in a simple way since it is not necessary to alter its basic structure³.

The model includes seven modules that can be modified freely in function of the necessities of the analysis at the moment:

- Market demand
- Distribution of firm sizes: capacity

- Imports
- Entries
- Managerial growth
- Production and costs
- Exits

THE MODEL

The model here developed is a structural model of entries and exits of dynamic character in which the new firms affect the market profitability and the survival possibilities of the other firms as well as the attractiveness that shows the market to possible new entries. Although the model is of passive learning (Jovanovic, 1982), that is to say, the companies do not know a priori which are their possibilities of success before they enter the market and compete, it could become easily a model of active learning (Hopenhayn, 1992) or one of external perturbations.

Two types of firms are considered in the model: on the one hand the originally established firms in the market and, on the other, those which entered the market step by step. This division of the firms in two groups has been made with a purely instrumental objective since this way in the model can be picked up the evolution of one only market as well as the quite common situation in the reality - but barely considered in the literature - where in a market a group of well established firms coexists together with the entrance and exit of companies of different characteristic generally less efficient and smaller.

The market demand

The perception of the consumer of an incomplete substitutability among the productions carried out by the incoming and the established firms suggests to include them in the demand functions with specific coefficients. This product differentiation can be justified by the different characteristics of the firms or simply because for the consumer the product of the established firms deserves more confidence as it is better known as that of the incoming ones. This formulation of the demand allows to include in the analysis certain segmentation in the market, going along with that mentioned in this sense by Acs and Audretsch (1989).

Distribution of sizes: capacity

The capacity of the companies settled down in the moment t_0 is distributed according to a lognormal function. This hypothesis on the distribution of the production is based on a wide evidence that indicates a

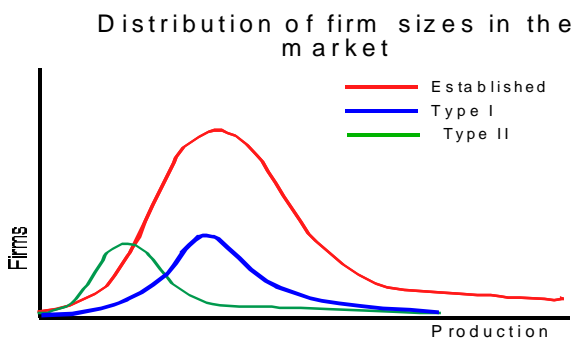
² As Löthgren (1997) points out the basic idea of this method is to approximate the sampling distributions of the estimator by using the empirical distribution of resampled estimated obtained from a Monte Carlo resampling simulation of the estimation procedure where repeated resamples of the observed data produce repeated estimates.

³ Dríade is able to pick up 2,880 different types of markets or basic models in its current configuration.

marked asymmetry in the distribution of market shares of the firms.

The capacities of the new firms that enter the market in successive periods also follow lognormal distributions similar to that of the established companies, although generally with different characteristics. The distribution of the new firms will be below of that of the established ones and its mode more to the left as they are habitually less in number and smaller (type I of graph 1). If the incoming ones had the same average size than the established ones then their distribution would have the same mode than those (type II of graph 1).

Graph 1



Entries

The number of new firms depend, in similar way as in the standard models of firms mobility, 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 expected benefits are defined as the average of Lerner Index observed in the previous period in the specific market where the entrances will take place. Although this hypothesis on the expectations that the incoming ones have about the expected benefits could be considered as excessively simplistic but it can be justified in certain way supposing that the entrance decision was taken in the previous period and that the effective entrance is taking place a period later. To suppose that the relevant market when considering the expected profitability is the market segment in which the entrance will take place constitutes a new contribution that allows to pick up situations broadly observed in the practice in which high entrance levels take place in spite of the fact that the observed margins in the whole market are low.

The margin of each of the groups of companies is calculated as the difference between its sales price and the average marginal costs of the firms that form the group to which it belongs.

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 barriers to the entrance of any other nature different to the economies of scale. This vector allows the inclusion in the model of institutional changes or external interferences that affect the entrances, favouring them or impeding them.

The exits are included in the equation of entrances by two reasons: first, a wide evidence points out the existence of a high correlation between both variables; second, there are solid theoretical arguments based on supply aspects as well as on demand (Storey and Johnson, 1987).

Also was included as variable favouring the entrances the "free space", that is to say, the number of firms of optimal size that still could enter the market without supposing a complete suppression of the margins. This variable seeks to pick up the better opportunities to the entries when the number of firms operating in the market is reduced as it is usually in the first phases of its development.

Firm growth

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 circumstances⁴. To integrate in the model this dynamic aspect, the size in period t is settled as a function of the size in the moment $t-1$. 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 a pondered average of both types of factors in which a coefficient determines the relative importance of each of the factors. If it is 1 then the growth is purely stochastic, while if it is 0 it is completely deterministic.

In the deterministic part of the pondered average a variable indicates the speed with which the firms adjust its capacity reducing its disadvantage with reference to the optimal one. The value 1 would indicate that the firms achieve in a single period the optimal size; on the contrary, the value 0 would indicate that the companies do not vary its production to arrive to the optimum.

Cost functions

It is considered that the available technologies are the same for all the companies of each group. So for each firm only exists one cost function that determines its

⁴ In later developments it has been made depend on the financial capacity and of the expectations of the firms.

average costs in function of its production level. It is maybe an excessive simplification but it has been adopted in order to make clearer the central object of the analysis. In any case the analysis could be centred on the industries where differences in the cost functions of the firms are small.

The cost functions used are Cobb-Douglas. This specification was chosen due to its considerable flexibility and its wide use in the literature.

The inclusion in the model of different costs between companies gives the model a higher degree of realism allowing, at least partly, to eliminate the problems pointed out by Tybout (1992) due to the consideration of only homogeneous firms.

The model also allows the introduction of differences in costs of the factors of the established firms and of the incoming ones. This aspect seems to have special relevance from the point of view of the relative competitiveness of incoming and established firms.

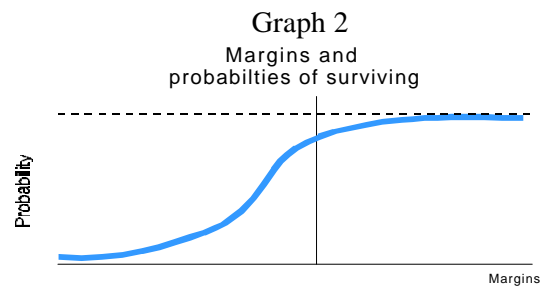
Production

Due to the lack of information of the firms about the real behaviour of their competitors, they consider that they behave the same way as the market at a whole; however, each one establishes individually the production level that maximises its benefit provided it is smaller or similar to its capacity, in which case they produce this. That means that the maximum production of the firms is limited by its capacity which only can be varied in the long term.

The firms estimate rationally each period the global market supply in order to decide its own production level that maximises 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 behaviour.

Exits

Although the profitability does not necessarily assure the survival of a firm, the probabilities of being expelled of the market depend mainly on its margin: it has less possibilities to survive the smaller the margin is. This relationship is not lineal since from certain levels of profitability on a significant increases 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 being expelled of the market (graph 2).



To pick up in the model this non lineal relationship, the probability of survival of the firms is defined as a Bernoulli distribution of parameter p , in which p is a logistical function that depends on the margin (Lerner index).

This specification of the function of exits picks up a fact broadly observed in the reality: the exit of a firm usually takes place because the results of a concrete exercise are so negative that a continuity of its activity in the market is not possible, or because it accumulates during several years not very favourable results.

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.

COMPUTER IMPLEMENTATION OF THE MODEL

The model was developed in MATLABM due to its capacity and easy use; additionally, as being a specific language for the mathematics, there are more similarities between the economic modelling and the computer science than using a language of general purpose like visualBasic, C++ or Pascal. The program is structured in modules representing partial aspects of the problem as the determination of the equilibrium price in the market, the entry of new firms or the determination of the managerial strategies that can be modified freely without affecting the rest of the modules. That helps to analysis the effects on the model when changing the exogenous variables or the initial hypotheses.

The program starts to create several matrixes that reflect the data of all the firms that potentially can exist in the market. The number of firms as well as the number of periods of the simulation is variable and the only limitation is the memory of the computer.

After the introduction of the exogenous variables, the initial number of firms and the coefficients that define the market characteristics (demand function, production function, type of firm growth and entry function) the simulation begins.

During the simulation the evolution of the main economic variables (production, size distribution of the firms, survival probabilities, employment, rates of entry and exit, margins, Herfindahl index, marginal costs....) can be observed through 18 graphics.

When finishing the simulation all results, those of the firms as well as of the markets, are stored in files for their later analysis by means of resampling methods.

VERIFICATION AND CALIBRATION

To verify the operation of the model avoiding the difficulties that could derive from the existence of random variables, the pseudo-random numbers that generate the simulations were fixed and the correction of each of the equations and subroutines was proven from the mathematical as well as the economic point of view. Once the reliability of the model using always the same random numbers was confirmed, its functioning with random seed values was proven.

The calibration of the model can be carried out by two different ways which need not be necessarily excluding, depending on the object of the analysis. The first one consists in the use of estimates for the coefficients and the exogenous variables coming from empiric studies on real markets. The second way consists in the introduction of alternative values, theoretically acceptable, in order to value the effect of the changes in the parameters on the general behaviour of the model, using statistical resampling methods.

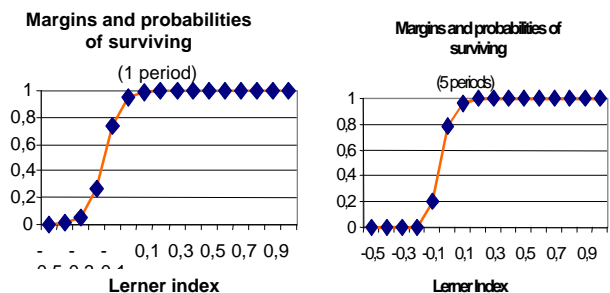
Although possible, the inclusion in the model of real data coming from specific markets is difficult due to the lack of data at individual level. On the other hand, the selection of a market of among all the possible ones could darken the analysis of the problem, as it does not serve to obtain general results. So the calibration of the model has been carried out using values theoretically acceptable obtained from related literature but which do not pretend to be a faithful image of any specific market.

The costs and production functions are standard Cobb-Douglas; although the values taken for the exogenous variables are arbitrary, they do not affect the conclusions that can be obtained from the model because they can be considered as scale changes.

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 analyse the behaviour of the population of firms for reasons exclusively deriving from the firms mobility.

The probability that the firms remain in the market depends on their margins; this makes that firms with narrow or negative margins exit especially if these bad results are repeated during several periods. Graph 3 shows the survival possibilities for one period and those that would have a firm that repeated their results during five periods. It can be appreciated how a firm with a negative margin of 0,1 has some high probabilities of surviving one period (73,1 percent), but if the bad results repeat during five periods the probabilities are reduced drastically (20,9 percent).

Graph 3



VALIDATION AND MAIN RESULTS

Once carried out the simulations, the model has been validated following the methodology of Kleijnen (1998) for situations where values for the exogenous variables are not available; that means, comparing the predictions of the model with the available evidence.

The developed model is fully compatible with the empirical literature, quite scarce about the evolution of the markets in the long term, as well as with the basic hypotheses of the Industrial Economy.

The number of firms grows during the first phases of the market development when the margins are high; as the entrance of new firms takes place the margins begin to decrease and the less competitive or less fortunate firms begin to exit.

The heterogeneity in the size of the firms plays an important role as stabilizer of the production and prices. The oscillations in the prices are more important the more homogeneous the firms are as the reduction of margins can produce an effect of "overshooting" expelling of the market more companies than strictly

necessary for the maintenance of the margins. This overreaction of the answer produces a quick increase in the prices with a rising number of entrances. This result is compatible with the phenomenon of the small-firm turbulence described by Beesley and Hamilton (1984).

The degree of heterogeneity of the firms of the market is not an absolute concept but rather depends on the intensity of the economies of scale.

The more important these economies of scale are less heterogeneity of firms is required so that the firms mobility does not produce strong oscillations in the number of firms and in the prices.

The firms mobility is able to generate by itself cycles in the production and the employment. Therefore it is not necessary that neither demand nor supply shocks take place in order to provoke periods of crisis in the markets.

The changes of leadership in the sector are more frequent when the margins are narrow. In periods of expansion the probabilities of exit of the firms are very reduced, especially of those that are bigger and more efficient. In the recessive phases, on the contrary, the probabilities of survival of the firms decrease so that, if there are no substantial differences in the costs between the leader and the followers, a substitution in the leadership can take place. In other words, in bad times to be the most efficient firm can not be enough to survive, while in good times it can be enough not being the worst.

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BIOGRAPHY

Federico Pablo Martí graduated in economics in the Faculty of Economics of the University of Alcalá, later made a Master in Administration of Energetic Resources in the University Pontificia de Comillas and the Spanish Institute of Energy and a Master in Industrial Economics in the Carlos III University of Madrid. After his graduation he started to work as assistant professor in the European University of Madrid. At present he works as academic secretary in the Faculty of Tourism of the University of Alcalá and is preparing his doctoral thesis in firms mobility.