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MARKET EQUILIBRIUM, CHOICE OF PRODUCTS
AND REGIONAL COMPETITION
IN THE AGRO FOOD INDUSTRY

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This paper presents a study of relations between industrial structures and market equilibrium where demand is uncertain. In the model used, the number of firms and their respective sizes and production structures are endogenous to the model.

The approach used is to determine first of all the sector's natural configuration and supply function. This means identifying the number and respective sizes of production units that together give the best price conditions for adjusting industry supply to one demand characterized by a distribution of probabilities.

The analysis is then broadened, taking coalitions, product choice and the spatial factor into account so as to analyse the impact of these parameters on market structures.
In a study of industrial structures and market equilibrium (C. Broussolle, 1990), using concepts from contestable markets theory and a model in which the number of firms and their respective sizes and production structures were endogenous to the model, we were able to identify equilibrium industry configurations. These are effective when the number of firms and the allocation of the vector of production among them minimize the total cost of production in the industry. Corresponding market structures are termed "natural".

In this article, we shall first examine the case where both independent firms and firms acting in collaboration are operating in the market. We shall then introduce plant localization and product variety as parameters. Besides the fact that it is useful to look at each of these separately in analysing industrial structures, it is also worth looking at both together, since geographical localization is considered an aspect of horizontal product differentiation. Regional competition and product competition thus enter into the same analytical framework. The aims are (a) to determine the natural configuration of a group of firms operating in different markets and (b) to assess the impact of plant localization and product choice on the structures of these markets.

I- THE MODEL

The group under consideration is that of firms competing in the markets where they sell their products. This group forms a structured network within which a flow of goods circulates.

Day by day analysis of orders placed with firms shows irregularity in terms of in quantities ordered, time intervals separating two successive orders, and delivery times imposed by customers.
These observations imply that orders (whether in backlog or in production) should be treated as a variable of state of the "firms/market" system.

Manufacturing Production and demand of products were monitored day by day for a year. The process being monitored proved to be Markovian, or comparable to a Markovian process, $p_i(n)$ being the probability of the system being in the state $E_i$ ($i=1,2,...,M$) at date $n$. The group of probabilities $p_i(n)$, which forms the group of vectors of state, describes the system for all future dates considered, probabilities $p_i(0)$ being known and constituting the initial vector for the following equations of state:

$$[p(n+1)] = [T][p(n)] \sum_{i=1}^{M} p_i = 1$$

The model is constructed around the firms, and there are as many decision-making centres as there are firms $E=(1,...,k,...,s)$. Each firm $k$ has one or more factories $U_k = (U_{kl1} \ldots U_{klr})$ and supplies, from its plants $I_{kl} = (I_{kl1} \ldots I_{kle} \ldots I_{klh})$, a range of products $q_{kle} = (q_{kle1} \ldots q_{klep} \ldots q_{kler})$, which are sold on markets $M = (1 \ldots j \ldots m)$ to meet demands characterized by distributions of probabilities.

The unit under consideration is quantity $i_{jk}$ of finished product delivered to one market and manufactured in one factory of one firm, from raw materials coming from one collection area. The corresponding "strategic segment" is described by four fields: type of product, factory, firm, market. The product is manufactured in fixed-capacity plants, each firm having a whole number of factories.

Output from a segment must meet uncertain demand, with delivery time constraints. Production capacity is such that the probability of demand not being met is below a certain threshold, this being reflected in excess production capacity.
The ratio of demand to total capacity, or plant utilization rate, expresses this relative difference. Supply adapts to demand by bringing one or several more plants into use.

For each segment there are corresponding unit costs: collection, production, delivery. The aggregate cost is the sum of these costs.

At the outset, there is a group of segments \( q^{ij}_{kle} \). Each segment calls into action one or several plants of a given type, to meet the demand and its delivery conditions. For each state there is a corresponding aggregate cost, or initial value of the target function. This aggregate cost is the sum of the expenses incurred by firms in supplying the range of products for which demand exists, knowing that the demand addressed to each segment is characterized by a distribution of probabilities.

To reduce this target function, the model simulates transfers of production from one segment to another. With a group of \( u \) segments, production can be transferred from a segment \( s \) to a segment \( t \) selected from among the \((u-1)\) remaining segments. Segment \( t \) is selected as being the one that optimizes the target function. Thus, each segment has its corresponding production transfer strategy. These strategies \((u \text{ in all})\) are compared.

Let the production transfer strategy for segment \( I \) be a switch to segment \( J \). The esperance of the new demand in connection with \( J \) is equal to the sum of the esperances of initial demands \( I \) and \( J \). We then calculate the number of plants of type \( J \) such that the probability of non-satisfaction of this new demand is below or equal to the chosen threshold.
For each segment $q_{ij}^{kle}$ this probability is expressed by the function $F$ below:

$$F(n, \Omega, d) = 1 = uo$$ with $u = e^{-nd(1-\Omega)}$

in which

- $n$ denotes the number of plants,
- $d$ a period of days,
- $\Omega$ the plant utilization rate of factory 1 of firm $k$, (between 0 and 1)
- $\bar{\Omega} = \frac{\beta}{n\mu}$ where $\beta$ is the esperance of demand for the product,
- $\mu$ the unit capacity of one plant,
- $u$ the probability that the wait will be longer than a given timelapse.

The factor $po$ is expressed in the following equation:

$$po = \frac{g}{\sum_{k=0}^{n-1} \frac{(n\bar{\Omega})^k}{k!}} + g$$

with $g = \frac{(n\bar{\Omega})^n}{n!(1-\bar{\Omega})}$

The number of plants $n$ of the new segment $J$ is the smallest whole number such that the quantity produced is greater than or equal to the demand. First the cost of production for $J$ is deducted, then the new value for the target function, on the hypothesis that the transfer strategy will actually be carried out.

This series of calculations allows classification of segments, and consequently of products, factories and firms, on criteria of competitiveness. This classification grades firms according to their contribution to adjusting supply to demand; from this classification, the natural market configuration can then be determined.
II- INDUSTRIAL SUPPLY AND NATURAL MARKET CONFIGURATION

We will examine in turn the case where firms are independent and the case where both independent firms and firms acting in collusion are operating in the market.

1- Independent firms

The natural configuration of a market is obtained from the industrial supply curve. This is the envelope of the marginal cost of substitution curves of the firms.

Let \( i \) be the product manufactured in factory 1 of firm \( k \). The model used enables us, as we saw, to grade units of production according to their competitiveness in the market. Supposing factory 1 of firm \( k \) lies in \( n \)th place, it is possible to find the minimal conditions (price, quantity produced, number of production units) that this type of factory must meet in order to gradually take the place of those above it (or below it), so as to meet the initial demand for the sector. In this way we can plot the marginal cost of substitution curve of product \( i \) manufactured in factory type 1, compared to the same product obtained from other factories ranking \( n-1, n-2, \ldots, 1 \) in the initial classification. An example of the curves obtained is Curve 1 in Graph 1. Following the same procedure for each firm and supposing - to simplify the presentation - that there are three firms, whose factories' sizes are \( \mu_1, \mu_2 \) and \( \mu_3 \) (\( \mu_1 < \mu_2 < \mu_3 \)), one gets curves 2 and 3.

The respective positions of these different curves are to be explained, in particular, by the trend of the esperance of the plant utilization rate as a function of demand, taking account of the sizes of the production units (Graph 2a). These utilization rates along with their corresponding unit costs (Graph 2b) show that theoretically less efficient plant is economically more interesting up to a certain threshold \( (\beta_{\text{P}}) \), as its utilization rate implies a lower average cost of
production than that recorded for larger-capacity plant (Broussolle 1989). As a corollary to this finding, we note that a (large) firm can only operate effectively in a market if the market is large enough.

Graph 1

From the marginal cost of substitution curves for each type of factory, one can determine the sectoral supply curve. This stepped curve is made up from the elements of curves 1, 2 and 3 the furthest to the right on Graph 1. The supply curve intersects the demand curve at coordinates P and Q and gives the natural market configuration, i.e. the industrial structure with which supply is in adjustment with demand under the best price conditions. The size of each horizontal segment measures the production capacity invested in one type of factory. Thus in the case in hand, the quantity $\bar{Q}$ of product sold at price $\bar{P}$ breaks down as follows:
- output $Q_1$ is supplied by firm 1,
- output $Q_2 - Q_1$ is supplied by firm 2 and quantity $Q - Q_2$ by the third firm, knowing that these firms' respective numbers of factories $n_1, n_2, n_3$, have been calculated using the model, and so may be different from those in the initial setup.
Of course, a certain number of firms and factories may be excluded from the natural configuration obtained. These are the ones with supply curves above the sectoral supply curve. Firms are excluded if their presence in the market is irrational owing to profit levels lower than those of firms in the natural configuration.

2 - Coalitions

In the most common case, there are firms operating separately in the market and also firms operating in coalitions. Coalitions may be restricted to simple cooperation, may go as far as merger, or may take a number of intermediate forms between these two extremes. What consequences does such collusion have for the natural market configuration? Let us take, as before, three firms $E_1$, $E_2$ and $E_3$, each of which has one or more factories, and let us imagine collusion between firms $E_1$ and $E_2$, whose unit costs of production are higher than those of firm $E_3$, and whose output is lower.

Apart from any other consideration, the collusion between firms $E_1$ and $E_2$ is reflected in the model by a pooling of the orders that were initially placed with each firm, and their distribution among the production units in such a way as to minimize manufacturing costs.

The three firms and the coalition $E_{12}$ are represented in Graph 3a by the points $U_i, U_j, U_k$ and $U^p$, $i, j, h$ and $p$ being their respective numbers of factories.

If the curves showing the trend in the mean plant utilization rate as a function of the esperance of demand, are associated with their corresponding unit costs (Graph 3b), one observes that coalition $E_{12}$ meets a greater demand than the sum of the demands that firms $E_1$ and $E_2$ could meet separately, and this at a lower unit cost than firm $E_3$. As a result, the demand channelled to $E_3$ is, all else being equal, necessarily
less than it was at the outset. Coalition E_{12} has thus proven its efficiency.

Graph 3a

Graph 3b
Based on these results, it is possible to determine at the same time the natural market configuration and the corresponding supply curve. As a first step, the resolution of the model allows us to classify coalitions and independent firms according to their competitiveness in the market. As a second step, we establish, as before, the marginal cost of substitution curves of the product manufactured in the factories of firms E1, E2 and E3 and coalition E12.

In fact, this gives three possible cases:

1- The natural configuration obtained is such that the coalition entirely replaces its member firms, and so provides the totality of their output.

2- The coalition considered is of no interest, in as much as its supply curve is above that of the natural market configuration.

3- The coalition is restricted to supplying a part of output \( (Q_{12} - Q_2) \), and member firms continue to supply separately a certain proportion of their respective initial outputs.

In the case shown here, it can be seen (Graph 4) that segments of the supply curve of coalition E_{12} are intermediate between those of firms E_{2} and E_{3}. As a result, to meet demand under the best price conditions, the natural market configuration is such that the quantities produced \( Q_1, Q_2-Q_1, Q_{12}-Q_2 \) and \( Q-Q_{12} \) are supplied, respectively, by firms E_{1} and E_{2}, coalition E_{12}, and firm E_{3}, and this in factories whose unit capacities are given, but whose respective numbers are supplied by the model.
III- MARKET STRUCTURES AND REGIONAL COMPETITION

The industrial structures observed are the combined result of (a) firms adapting to existing technical and economic conditions and (b) strategies adopted by economic agents to modify their environment. From this standpoint, choice of plant localization is as important as product choice. Both aspects involve the same set of problems in that product localization is one of the characteristics of horizontal product differentiation. Broadening the study to bring in the spatial factor therefore means extending the sphere of characteristics of each product to take account of the localization of the markets where it is sold. The firms potentially concerned by these diversified demands will seek to appropriate market shares. They will integrate transport costs connected with geographical localization into their cost price. Under these conditions, and knowing that for the first stage these localizations are given, the problem is to determine those equilibrium configurations that integrate the spatial factor;
as geographical space operates solely as the medium through which goods flow, and as an additional source of costs. In fact, even in this case, some further hypotheses have to be made about the localization of the production units to be created when determining the supply curve for a firm that is gradually replacing the firms above it in the initial classification.

Let us consider a group of n firms manufacturing one product and able to supply m markets in part or in full. As a first step we determine the natural configuration of these n firms in each market. As a second step, the results are compared market by market, to show whether they are compatible and, if not, to identify the conditions under which they would become so.

In fact there are two possible cases. In the simpler and less likely case, one finds different firms in each of the configurations obtained. Under these conditions no regional competition problem arises. But this problem does arise if, in the natural configurations of some markets, the same firms are solicited for levels of output that are mutually incompatible.

To simplify the presentation, let us suppose that inter-firm competition occurs in two markets, M₁ and M₂, and that a simultaneous search for natural configurations in these markets has led to selection of the factories of firms E₁ and E₂ for the first market and those of firms E₁, E₂ and E₅ for the second (Graph 5).

In market M₁, supply from firms in the natural configuration is shown by the stepped curve ABCDE which intersects supply curve D₁ of market M₁ at coordinates P₁ and Q₁. It can be seen that output AB is supplied by firm E₁ and output CD by firm E₂. Firms E₃, E₄ and E₅ are excluded from the equilibrium configuration of market M₁.
the supply curves for these configurations. Of course, a certain number of firms may be excluded from the market for some or all of the varieties it supplies. The presence of a firm on one or several of these supply curves justifies, for given output levels, the manufacture of one or more varieties of the product under consideration. More broadly, this gives the product range for which each firm is competitive.

Although the methodology is identical, it should be noted that geographical localization regarded as an aspect of horizontal product differentiation is a cause of further constraints in establishing supply curves. Sale by several firms of different products in the same market is not equivalent to sale by several firms of a single product in different markets. In the latter case, if a firm cannot meet demand in several markets simultaneously in the same niche of the supply curve, and if the firm concerned is not in a dominant position, choices will be "imposed" upon it. The same applies if horizontal product differentiation does not take account of the spatial factor.

2- Natural configurations and vertical product differentiation

The cost of production of a product obviously depends on its quality, and quality range will therefore be reflected in product prices. Consequently, while for a given firm there is only one demand function for a given product, there is on the other hand a supply function for each quality of this product. Under these conditions, a natural configuration exists for each quality, and the presence of a firm on one or more of the supply curves for these configurations indicates, for given output levels, the range of qualities for which it is competent.
Of course, most products are supplied both in a range of varieties and at different quality levels. Study of this common case involves combining the results of the earlier analyses, and also raises some specific problems to be addressed in forthcoming research.

CONCLUSION

The concepts employed and the use of a model in which the number of firms and their respective sizes and production structures are endogenous to the model enable selection, in a random universe, of the most efficient firms. Furthermore, by modifying, under certain conditions, the configuration so obtained, coalitions can in some cases change the nature of competition.

Of course, the industrial structures observed are the combined result of firms adapting to existing economic and technical conditions and of strategies adopted by economic agents to modify their environment. From this standpoint, and treated in the same way as product choice, plant localization is one of the variables firms can manipulate to influence market structure. Both aspects involve the same group of problems insofar as product localization is one of the product differentiation factors that define viable firms.


