INNOVATION, PRODUCTIVITY GAINS AND THE EVOLUTION OF MARKET STRUCTURE

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The paper analyses the co-ordinating role that markets and organisations are called on to play in determining productivity gains. In fact, the viability of innovation processes cannot be dissociated from the way market structures emerge and evolve. The success (or not) of the introduction of new technologies and the emergence and evolution of given market structures does not depend on the properties of technology, but on the capacity to coordinate the activity of the different firms participating in the restructuring process, which results in a certain degree of stability of the market structure.

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1. Introduction

Modern economic analysis focuses on first principles and hence on fundamentals (that is, on properties of technologies, preferences and information structures) in order to simultaneously explain firms' performances and market structures.

Within this analytical framework, a superior technology coupled with market rules that better determine the incentives to adopt it will result in higher performance, at both micro and macro level. Co-ordination problems are supposed to be solved *ex ante* by an invisible hand or by strategic interaction between economic agents. This puts the weight of the firms' (and of the economy's) performances on the intrinsic character of technology and the prevailing institutions. However, the contradictory performance of the so-called 'new economy', which it was thought would enable a great jump forward, has cast doubts on the alleged role of certain technologies and institutional frameworks as a major factor of economic growth. This shifts the focus on the co-ordination mechanisms required to make the innovation process which firm performance and hence the growth of the economy actually depend, more viable. Although there is strong evidence that technical and market conditions have changed greatly with the emergence of new technologies, it should be remembered that the same basic co-ordination problems remain to be solved in the context of the new economy.

Economies of the new age, like those of the older era, experience biased technological progress, characterised, with reference to a Neo-Austrian analytical framework (Hicks, 1973), by an increase in the construction costs of the productive capacity which is more than compensated for by a decrease in its utilisation costs[1].

In particular, innovation results in a breaking down of the time structure of the existing productive capacity, which induces the appearance of co-ordination problems both at firm and industry level. In a restructuring process costs and proceeds are no longer synchronised, and hence supply and demand are also no longer equal at each moment of time and over time. Reactions to these imbalances result in fluctuations that may be a threat to the viability of the innovation process. How these co-ordination problems are dealt with is what actually determines the performance of the firm. The market is also affected by this process. The viability of innovation processes cannot be dissociated from the way that market structures emerge and evolve.

1. Clearly, information and communication technologies (ICT) tend to increase the capacity of the economy to deal with variety. "This has led to decreases in the cost of switching from one series to another, from one product to another" (Zuscovitch, 1998: 252), that is, to decreases in the utilization costs of a larger gamut of products and services. However "this tendency calls for a massive incorporation of science and technology in specific configurations to match this specified variety", which generally involves higher construction costs.

Building on the insights in the Marshallian and the Schumpeterian approaches we focus on the co-ordination role that markets and organisations are called on to play in order to make the innovation process viable. We interpret competition as the main co-ordination mechanism involved in this process and argue that competition can not only co-exist with increasing returns, but helps firms to capture them. We will show that a stabilisation of the market structure, not just a particular feature of it, is required for successful innovation (and returns to be realised). However, competition may, or may not, lead to stabilisation. It is really successful when prices and quantity adjustments are carried out, which make it possible for firms to obtain normal profits, that is, when these adjustments do not result in a waste of productive resources.

The paper is organised as follows. Section 2 analyses the nature of co-ordination problems involved by innovation processes. Section 3 provides a model that allows these problems to be analysed. Section 4 describes, by means of simulations, the behaviour of the model, and presents the main results. Section 5 concludes with some analytical and policy considerations.

2. Innovation and Sunk Costs: the Nature of Co-ordination Issues

According to the standard approach, technology is given, in that it has an already defined specific character. Innovation is then reduced to the decision to adopt new technologies, with which given results are associated. According to our approach, innovation is a process of research and learning that may, or may not, result in the appearance of new productive options and new productive structures. In this sense it is a process of 'creation of technology', which, when (and if) successfully brought about, makes it possible to actually transform the potential increasing returns of technology into growth and monetary gains for firms and consumers. This process implies the break up of the existing industrial structure and the modification of market conditions, followed by a gradual reshaping.

Co-ordination is required in the first place to re-establish the harmony between construction and utilisation, disturbed by the structural modification involved, so as to avoid strong imbalances between costs and proceeds and between supply and demand of final output. However, co-ordination occurs not only at the individual firm level but also at the system level. Most innovations do not arise as the result of the independent actions of single innovating firms, but are the result of new forms of co-ordination across several heterogeneous firms. There is interaction between co-ordination of the production process and co-ordination between firms.

Co-ordination problems mainly arise from the existence of sunk costs associated with the restructuring of productive capacity. The focus on sunk costs and the two faces of the co-ordination problem involved are common to the New Industrial Organisation (NIO) approach, but the role that we attribute to them is rather different.

In the NIO approach, sunk costs are construction (investment) costs, "a fascinating aspect of (which) is their commitment value" (Tirole, 1988: 314). This commitment refers to a multi-period context and represents a credible threat, which is essential to the determination of market structure. However, the sunk costs in turn depend on market structure and are determined simultaneously with the latter. This is because sunk costs are determined once the market game that defines market equilibrium is known. Everything is defined following a backward induction process that implies an analytically instantaneous determination of all the relevant magnitudes. Sutton's (1991, 1998) version of NIO is less extreme: he abandons the aim of identifying a unique equilibrium outcome in a given multi-period context. "Instead we admit some class of candidate models (each of which may have one or more equilibria) and ask whether anything can be said about the set of outcomes that can be supported as an equilibrium of any candidate model" (Sutton, 1998: 6-7). This set of outcomes must satisfy two conditions: the viability condition— which means that each firm covers its sunk cost over the multi-period domain— and the stability condition— which allows a certain market structure to be preserved. Although essentially different our treatment of sunk costs has some relation to Sutton's analysis in its focus on viability and the market structures compatible with it.

However, in our analysis, sunk costs are not only an expression of the existence of investment costs, but also of the divorce between costs and proceeds at each step in the evolution process triggered by the breaking up of the intertemporal complementarity of the production process as a result of the attempt to conduct innovation. Intertemporal complementarity is the main feature of a process of production that stresses the relationship between the phases of construction and utilisation of productive capacity. It is assured, by definition, in equilibrium. When it is no longer assured, costs are dissociated in time from proceeds and hence become 'sunk' costs. The characteristic of the sunk costs of investment in a process, which implies a structural change, is that they will only be recovered when (and if) the process itself is actually established. This involves not only taking account of the whole period of construction of the new productive capacity— which is likely to have a considerable length as, before construction in a proper sense, it implies experimenting, pilot plans, and so forth— but going beyond that point, until the stream of receipts from the new output has reached a certain size and the change has thus proved viable. The point to be emphasised here is that, in a context of gradual reshaping, costs depend not only on current production, but also on the length of construction of the new productive capacity, on the length of utilisation of this capacity, and on the total volume of output produced over successive periods (Alchian, 1959). These are not data, but the results of the process itself. When, for example, excess productive capacities result in lower rates of utilisation and/or in production processes being scrapped, then there are changes in production costs, and hence in viability conditions. These changes actually express co-ordination failures that emerge as a consequence of a break down in the intertemporal complementarity of production processes.

Firms do not know *ex ante* whether it pays to innovate.

Indeed the answer to this question for any single firm depends on the choices made by other firms, and reality does not contain any provisions for firms to test their policies before adopting them. Thus there is little reason to expect equilibrium policy configurations to arise. Only the course of events over time will determine and reveal what strategies are the better ones. (Nelson and Winter, 1982: 286)

From this perspective competition can no longer be considered as a particular *state of affairs*. It is not only aimed at equalising supply and demand in a given market and technological environment, but "has also to adapt both structure and technology to the fresh opportunities created by expanding markets" (Richardson, 1975: 353). It must be viewed as *a process of trial and error,* an essential moment in which is the discovery of information about the behaviour of competitors and customers (Hayek, 1937). This behaviour has feed-back effects on what happens inside each firm in terms of the relation between costs and proceeds, the relationship on which the viability of the innovation process and the emergence of a particular market structure eventually depends.

3. A Sequential Model

The course of events that characterises an innovation process is analysed by means of a model derived from Amendola and Gaffard (1998), which makes it possible to exhibit the time structure of production processes and to sketch the sequential interaction of decisions in the process of restructuring productive capacities.

For each firm *i*, the state variables are: $x^i(t)$, the vector of production processes, $m^i(t)$, the revenue from sales, $h^i(t)$, the monetary idle balances, $o^i(t)$, the stock of final output, $\omega^i(t)$, the wage fund, $\psi^i(t)$, the available human resources, $d^i(t)$, the volume of final demand, $s^i(t)$, the volume of supply, $\delta^i(t)$, the market share. The control variables are: $x_1^i(t)$, the rate of start of production processes, $u^i(t)$, the rate of scrapping of production processes, $\tau^i(t)$, the rate of utilisation of productive capacity, $p^i(t)$, the price of final output, $w^i(t)$ the wage rate, $f^i(t)$, the external financial resources which depend on banking policy, $\eta^i(t)$, the fraction of total real stocks actually put back on the market.

3.1. The structure of productive capacity

In each firm i production is carried out by means of processes of a Neo-Austrian type. An elementary process of production is defined by the input vector:

$$a_j^i = [a_{jk}^i] ; \text{k} = 1,.., n^c + n^u$$

whose elements represent the quantities of labour required in the successive periods of phase of construction c (from 1 to n^c) to phase of utilisation u (from $n^c + 1$ to $n^c + n^u$) of the productive capacity of commodity j, so that:

$a_j^i = [a_j^{ic}, a_j^{iu}]$ with $a_{jk}^i = a_j^{ic} \forall k = 1 ,..., n^c$ and $a_{jk}^i = a_j^{iu}, \forall k = n^c + 1$, ..., $n^c + n^u$

and by the output vector:

$b_j^i = [b_{jk}^i]$ with $b_{jk}^i = 0 \forall k = 1 ,..., n^c$ and $b_{jk}^i = b_j^i, \forall k = n^c + 1$, ..., $n^c + n^u$

At each given moment t the productive capacity of a commodity j by firm i is represented by the intensity vector:

$$x_j^i(t) = [x_j^{ic}(t), x_j^{iu}(t)]$$

each element of which is a number of elementary production processes of a particular age, either still in the construction phase or already in the utilisation phase.

At each given moment of time the productive capacity of the firm i is given by the vectors:

$$x^i(t) = [x^{ic}(t), x^{iu}(t)]$$

whose elements are the number of processes in construction, $x^{ic}(t)$, and in utilisation, $x^{iu}(t)$ referring to all the technologies in use ($x = \sum_j x_j$).

The productive capacity is subject to ageing and to modifications due to investment and scrapping. Scrapping of production processes $u(t)$ occurs when resource constraints are so stringent as not to allow all the processes inherited from the past to be carried on. An alternative to scrapping is a partial use of the utilisation processes, which, however, implies a cost, as we shall see when we consider the rate of utilisation of existing productive capacity. We assume that the firms choose a less than full degree of utilisation to allow for an over-normal functioning of the existing capacity to enable 'capacity competition' (see below).

In each period the level of activity (both investment and current production) of each firm (or of the representative firm) depends on its wage fund $\omega^i(t)$, which is constrained by available financial resources $F^i(t)$ or, alternatively, by available human resources $\psi^i(t)$:

$$\omega^i(t) = \min [F^i(t), w^i(t)\psi^i(t)]$$

3.2. Financial resources constraint

The available financial resources $F^i(t)$ are:

$$F^i(t) = m^i(t-1) + h^i(t-1) + f^i(t) - c^i(t)$$

where the internal financial resources are given by $m^i(t-1)$ the money proceeds from the sales of final output, the idle money balances involuntarily accumulated in the past and ready for use are given by $h^i(t-1)$, the external financial resources by $f^i(t)$, and the take-out by $c^i(t)$, which is the current resources withheld from the financing of production (consumption by producers, transfers, and so forth).

Within the sequential setting considered prices are fixed within each given period and can only change at the junction of one period with the next one. As a consequence money proceeds are given by:

$$m^i(t) = \min\,[p^i(t)d^i(t), p^i(t)s^i(t)]$$

Real stock changes $\Delta^i o(t)$ are substitutes for price changes, which cannot take place within the period. Excess supply results in an accumulation of undesired stocks for the firm:

$$\Delta o^i(t) = o^i(t) - o^i(t-1) = \max\,[0, s^i(t) - d^i(t)]$$

where $s^i(t)$ and $d^i(t)$ are current real supply and real demand (for the different and successive technologies), respectively.

External financial resources are such that:

$$f^i(t) = \min\,[f^i_s(t), f^i_d(t)]$$

where $f^i_s(t)$ stands for the borrowing power of the firm, and $f^i_d(t)$ is the demand for external financing resulting from the production and investment decisions actually taken. External financial constraints are formally exogenous in the model. Different financing scenarios, which imply consideration of the relation between external finance and the viability of innovation processes, can be explored.

3.3. Human resources constraint

The available human resources depend on a natural growth rate of population and on wage elasticity:

$$\psi(t) = (1+g)^t L(0) w(t)^{\varphi}$$

where g is the natural growth rate, w the (industry average) wage rate, and φ the wage elasticity of labour supply.

A general human constraint may appear to be due to insufficient growth of the labour force. When the human constraint is more stringent than the financial constraint money balances are involuntarily accumulated:

$$h^i(t) = \max\,[0, m^i(t-1) + h^i(t-1) - \omega^i(t)]$$

3.4. Aggregate demand and market share

The aggregate market demand, D, is determined as follows:

$$D(t) = (1 + g)D(t-1)p^{\theta}(t),\ \theta \leq 0$$

where g is a given exogenously determined growth rate, and θ demand price elasticity.

The average market price is given by:

$$p(t) = \frac{\sum_i p^i(t)s^i(t)}{\sum_i s^i(t)}$$

The market shares are: $d^i(t) = \delta^i(t)D(t)$ with $\delta^i(t) = \frac{\left(\frac{\delta^i(t-1)}{p^i(t-1)}\right)^{\beta}}{\sum_i \left(\frac{\delta^i(t-1)}{p^i(t-1)}\right)^{\beta}}$

that is, a firm's market share depends on the relation of its price to the average market price in the preceding period.

With β less than one, more or less constant market shares obtain when the prices charged by the firms are different. This looks like a Chamberlinian competition. With β greater than one, on the other hand, the firm which, at one moment, has the greater market share, has the cumulative advantage which results in the exit of some other firms. This looks like a situation characterised by the increasing returns of adoption.

3.5. Investment and production decisions

The evolution of each firm is actually determined by the behaviour of the decision variables, namely, the rate of start of new production processes $x_1^i(t)$, the rate of utilisation of productive capacity τ^i, the price of final output $p^i(t)$, the wage rate $w^i(t)$, the ratio $k^i(t)$ of the external financial resources $f^i(t)$ to the money proceeds from the sales of final output $m^i(t)$ (i.e., the firm's borrowing power), and the scrapping rate $u_k^i(t)$.

Each firm determines the rate of start up of production processes in such a way that the productive capacity available $n + t^c$ periods later will match expected demand:

$$x(t) = \max\left[0, \frac{\tilde{d}^i(t+n^c) - \tilde{q}^i(t+n^c)}{\bar{\tau}^i b^i_{n^c+1}(t+n^c)}\right]$$

where $\tilde{d}^i(t+n^c)$, is the real demand expected by the firm i for the period $t+n^c$, computed by extrapolating the average growth rate of real demand registered in previous periods and $\tilde{q}^i(t+n^c)$ is the output that will be obtained from the productive capacity available at period $t+n^c$, the construction of which began before t, so that:

$$\tilde{q}^i(t+n^c) = \bar{\tau}^i \sum_{k=2}^{n^u} b^i_{k+n^c}(t+n^c) x^i_{k+n^c}(t+n^c)$$

where $\bar{\tau}^i$ is the desired rate of utilisation of the productive capacity.

Different investment behaviours may be considered by introducing more or less stringent limits to the variations of the *desired* rate of starts from one period to the next: limits that represent more or less aggressive investment behaviours. In fact, firms take investment decisions based on expected demand, but they also know that the volatility of investments is a threat to their survival. So the change in the rate (whether an increase or a decrease) of start ups of new production processes from one period to the next is bounded, which sets a limit to the 'capacity competition' that would otherwise take place. This kind of competition depends on the fact that in a truly sequential context firms cannot predict the result of the market game. Thus, when they make investment decisions based on expected demand, they discount increases in productivity resulting from their own innovations, but not those realised by competitors. This is likely to bring about excess productive capacities with respect to existing demand, and pushes competing firms into 'capacity competition' aimed at stealing market share from one another.

Each firm determines current production by fixing the current rate of utilisation of its productive capacity, $\hat{\tau}^i$, so as to adjust its current supply to expected final demand $\hat{d}$:

$$\hat{\tau}^i(t) = \min\left[1, \frac{\hat{d}^i(t) - [o^i(t-1) - o^i_d(t)]}{\sum_{k=1}^{n^c+n^u} b^i_k x^i_k(t)}\right]$$ where $\hat{d}$ is such that:

$$p^i(t)\hat{d}^i(t) = \frac{m^i(t-1)^2}{m^i(t-2)}$$

that is, expected final demand is made to depend on the firm's past revenue trends, and o^i_d are the stocks that the firm wants to keep.

As a result of the production and investment decisions the actual wage fund is given by $\omega^i(t) = w^i(t)\Lambda^i(t)$ where is the labour demand given by:

$$\Lambda^i(t) = \sum_{k=1}^{n^c+n^u} A_k^i(t) x_k^i(t) \rho_k^i(t)$$

where ρ_k^i are the elements of the vector ρ^i, which allows the consequences on the labour demand of a variation in the rate of utilisation of the productive capacity to be taken account of:

$$\rho^i(t) = [\rho_1^i(t), ..., \rho_{n^c}^i(t), ..., \rho_{n^c+n^u}^i(t)]$$

with: $\rho_k^i(t) = 1 \quad \forall k, 1 \le k \le n^c$ and: $\rho_k^i(t) = \tau^i(t) + \zeta^i(1 - \tau^i(t))$ $\forall k, n^c + 1 \le k \le n^c + n^u$, where ζ^i is the labour required to maintain a process of production idle.

3.6. Price and Wage Decisions

The price charged by each firm is determined as follows:

$$p^i(t) = \frac{w(t) \sum_{k=1}^{n^c+n^u} a_k^i \rho_k^i(t)}{\bar{\tau}^i \sum_{n^c+1}^{n^c+n^u} b(t)}$$

That is, it is determined in such a way as to cover the cost of production when using the productive capacity, which is the expression of the technology adopted, at the desired rate of utilisation of this productive capacity. This price is determined, step-by-step, with reference to the new technology adopted each time, to the moment this first reaches the phase of utilisation. This is how each firm implements price competition.

This price can be adjusted as mentioned above in order to relax the financial resource constraint:

$$p^i(t) = p^i(t) + \sigma^i \frac{[\tilde{x}_1^i(t-1) - \hat{x}_1^i(t-1)] a_1^i w^i(t-1)}{\hat{d}^i(t)}, 0 \le \sigma^i \le 1$$

where $\tilde{x}_1^i$ is the desired rate of start ups, and $\hat{x}_1^i$ is the rate of start up constrained by the available financial resources.

It can also (and alternatively) be adjusted in reaction to the market disequilibria perceived in the previous period:

$$\hat{p}^i(t) = p^i(t) + \chi^i \frac{[d^i(t-1) - s^i(t-1)]}{s^i(t-1)}, 0 \leq \chi^i \leq 1$$

Moreover changes in price from one period to the next are both upward and downward bounded.

The wage rate is endogenous to the model, being determined by the partially exogenous supply of labour and the endogenous demand for labour. Changes in the wage rates paid by each firm reflect the disequilibria arising on the labour market, that is:

$$w^i(t) = w^i(t-1)\left[1 + v^i \frac{\Lambda^i(t-1) - \psi^i(t-1)}{\psi^i(t-1)}\right]$$

where v^i is a reaction coefficient.

As already mentioned, firms are wage makers on local labour markets. Each firm, through its wage policy, can relax the human resource constraint. Competition in the labour market implies that each firm obtains a fraction of the labour supply ψ^i, which depends on the relative wage it pays to its workers:

$$\psi^i(t) = \phi^i(t)\psi(t) \text{ with } \phi^i(t) = \frac{[\phi^i(t-1)w^i(t-1)]^{\varepsilon}}{\sum_i [\phi^i(t-1)w^i(t-1)]^{\varepsilon}}$$

With ε less than 1, the distribution of the labour supply across firms is more or less constant while their wages are different. With ε greater than 1, on the other hand, the firm which, at one moment, has the greater share of labour supply, benefits from a kind of cumulative advantage, which implies that more and more workers prefer to be hired by this firm whatever the wages it pays.

Competition between firms results in different, but converging wage rates.

3.7. Banking Policy

External financial resources are such that:

$$f^i(t) = \min[\text{k m}^i(t-1), f_d^i(t)]$$

where k stand for the borrowing power of each firm, and $f_d^i(t)$ is the demand for external financing resulting from the production and investment decisions actually taken.

External financial constraints are formally exogenous in the model. Different financing scenarios, which imply consideration of the relation between external finance and the viability of innovation processes, can be explored. A specific value for k might express the opinion (and the decisions) of financial markets and / or bankers.

3.8. Innovation, imitation, entry and exit

A firm can introduce a new technology by innovating or imitating. Innovation means embarking on a process, which should enable a better performance than possible by firms using older technologies. Imitation consists of copying prevailing best practice. Probability distributions that are independent from firm to firm, but in the same distribution generate innovations as well as imitations for all firms and over all periods.

Market structure evolves endogenously. On the one hand, as already mentioned, price variations provoked by cost variations result in changes in market share. Any firm whose market share falls below a given threshold (e.g. 1%), for whatever reason (too high price or lack of resources), exits from the market, but only one firm can enter the market in each period of time.

Entry is modelled as a random process, characterised by an independent random variable *new-entry* which takes on the values 1 or 0 according to whether a new firm does or does not enter. Effective entry occurs with the probability:

$$\Pr\{\text{new} - \text{entry}\} = \pi.[\Gamma(t)]$$

where Γ is the rate of industry excess demand calculated over a given number of previous periods.

The size of a new entrant is equal to a targeted market share (e.g. 50% of the existing excess demand at industry level). This threshold may be considered as the strength of the financial constraints that the new firm must work within.

3.9. Firms' performance and market concentration

The performance of each firm is measured by its unit margins, whereby a unit margin is defined, in each period, as the ratio of the difference between the price (calculated as mentioned above) and the current unit cost of output— obtained by dividing the total cost of production of the amount of output obtained in that period by the same amount— to the price itself:

$$\mu^i(t) = \frac{p^i(t) - c^i(t)}{p^i(t)} \quad \text{where:} \quad c^i(t) = \frac{w^i(t)\Lambda^i(t)}{q^i(t)}$$

Unit margins on average equal to zero mean that firms realise normal profits. Unit margins will be negative at the beginning of any innovation process, which is necessarily characterised by higher construction costs. This illustrates the initial competitive disadvantage suffered by innovative firms. On the other hand, negative unit margins may be indicative of excess capacities, that is, of a lower degree of utilisation of productive capacity with respect to desired levels, and vice-versa.

Market concentration is measured by the Herfindahl index.

4. The Innovative Process

While standard models of oligopoly or monopolistic competition generally deal with the degree of competition and the characteristics of industrial structures as determined by given information and cost conditions, our model is directed towards a dynamic process of rivalry such as determined by *changing* costs and information conditions. This process may result in a waste of productive resources and no real advantage for customers or, alternatively, may allow firms and/or customers to benefit from increasing returns. It can likewise result in a very unstable market structure, or in a fairly stable structure.

Within this framework, the character of the shocks that occur in each period is not important. These shocks always come down to a demand for new productive resources, which result in a productive structure that allows the benefits of the change to be realised only if the co-ordination problems raised by the shocks themselves are properly dealt with.

Let us consider a market in which two or more firms compete with one another by innovating, whether at the same time or sequentially. Technological changes are 'forward biased', in a sense similar, but not equal to, the definition in Hicks (1973), that is, increasing construction (labour) costs are more than compensated for by increasing output rates. At the beginning of the experiment the firms considered have an equal share of the market and face an aggregate final demand which is growing at a given rate (5%). There are no biases in the functioning of the product and labour markets ($\beta = 1$ and $\varepsilon = 1$). Prices are determined with regard to a structure of productive capacity (embodying the more recent technology) capable of sustaining a steady state: in other words they are fixed at a level that corresponds to the average long run unit cost associated with the prevailing technology. Cost changes, not automatically reflected in prices, therefore have an immediate negative effect on unit margins. Finally, there are free entry and exit conditions.

We assume that innovation perturbs an industry that at the beginning of the simulations is in equilibrium. This means in particular that in each firm the investment carried out is sufficient to retain consistency during the construction and utilisation phases of productive capacity, and at the same time that it is related to the investments of the other firms such that the market structure remains stable. A technological shock destroys both the internal consistency of the capital structure of the firms involved and the equilibrium among firms. What happens within firms also affects relations among them, and vice-versa. This means that investments will become either insufficient or excessive in relation to those required to keep both the internal and the external equilibrium of the firms' productive capacity. This reflects the existence (or not) of a resource constraint: a financial constraint and/or a human resource constraint in our modelling. Together with the prevailing price and wage change regimes and the specific features of the environment (in particular, the original number of firms in the market), this will determine the viability or not of the adjustment process triggered by the shock considered.

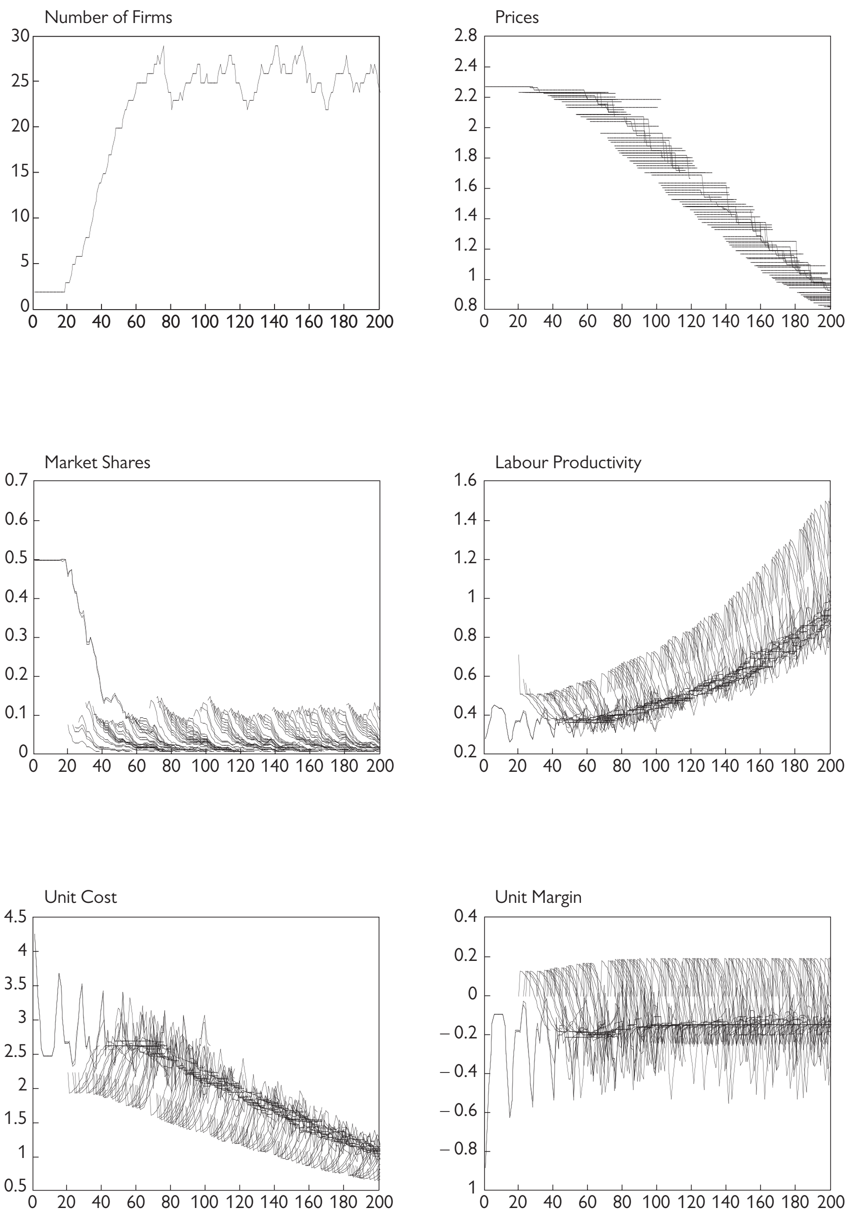
A strong resource constraint (whether financial or human) prevents excess capacity competition between the incumbents from becoming too strong, and hence favours the profitable entry of new firms, presumably with the required funds, given that targeted market share is exogenously determined. With a limited number of firms at the beginning (N=2 in our experiments) and a strong financial constraint (k=0.2)— figure 1— the following entry-exit process is characterised by a concentration index that decreases before it is stabilised. Costs are diminishing, although through fluctuations, which means that the productivity gains associated with the new technologies are actually obtained. Unit margins, necessarily negative at the beginning of any innovation process which is characterised by higher construction costs, converge towards a more or less normal level. The robustness of these results is attested to by the synthesis achieved by multiple runs corresponding to different values of the randomly chosen variables, which show an increase followed by stabilisation of the average number of firms existing in the market, and an increase followed by a decrease in the mean dispersion of market share (figure 2).

When the human resource constraint prevails over financial constraints, this, holds only if the wage reaction coefficient is equal to zero, or sufficiently low (ν=0.05), that is, when the scarcity of labour does not bring about wide variations in wages (figure 3). If the wage reaction coefficient is too high, and this is coupled with too high wage elasticity in the labour supply, a very unstable market structure prevents innovation processes from being viable (figure 4).

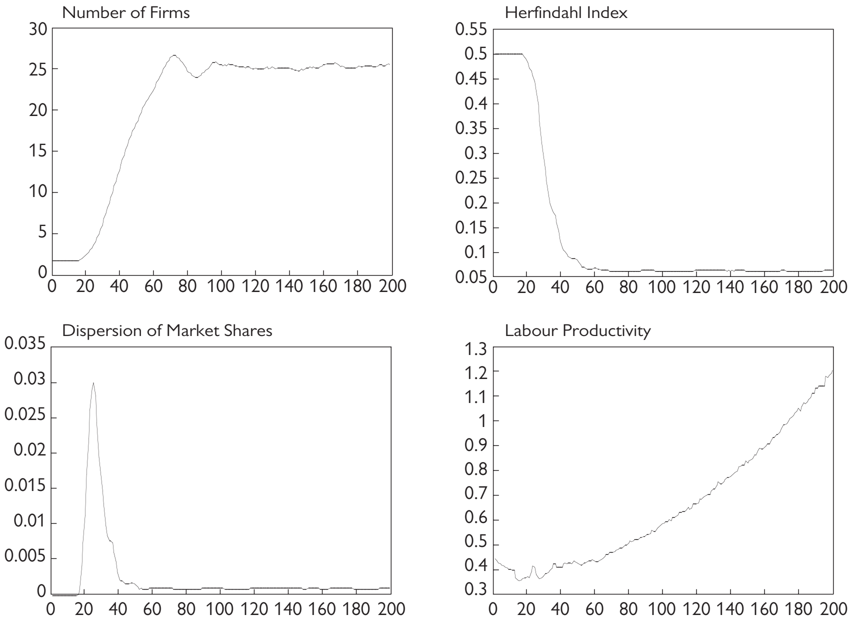
This also holds whatever the initial number of firms. In the case of an initial atomistic structure (N=50), a shake out process takes place, which results in a stable market structure. Then the gains from innovation are realised (figure 5). Under specific co-ordination conditions, the industry converges towards dynamic equilibrium. This holds whatever the value of β: when $\beta > 1$, that is when increasing returns to adoption prevail, the only change is that the number of firms that characterise dynamic equilibrium will be smaller (figure 6).

On the other hand, with a small number of original incumbents (N=2), weak external financial constraints (k=1) favouring investment on the part of the incumbents themselves, make it difficult for new firms to enter and

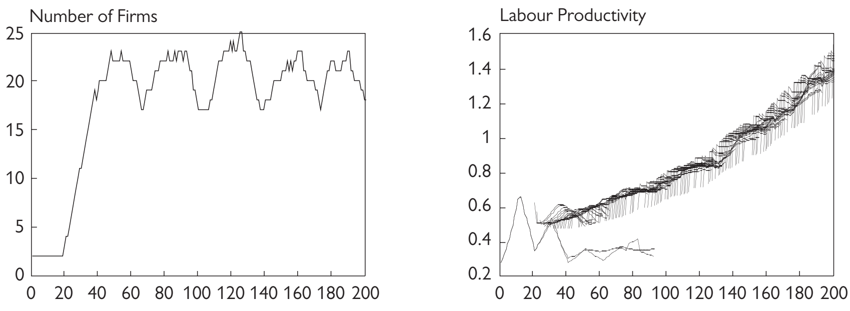
1.


Number of Firms
30
25
20
15
10
5
0
0 20 40 60 80 100 120 140 160 180 200
Prices
2.8
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0 20 40 60 80 100 120 140 160 180 200
Market Shares
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100 120 140 160 180 200
Labour Productivity
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0 20 40 60 80 100 120 140 160 180 200
Unit Cost
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0 20 40 60 80 100 120 140 160 180 200
Unit Margin
0.4
0.2
0
– 0.2
– 0.4
– 0.6
– 0.8
1
0 20 40 60 80 100 120 140 160 180 200

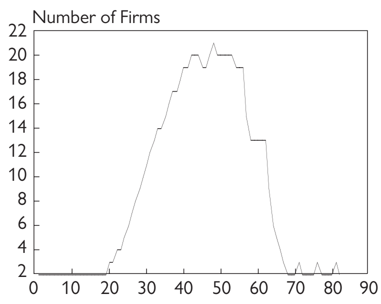
2.


Number of Firms
30 25 20 15 10 5 0
0 20 40 60 80 100 120 140 160 180 200
Herfindahl Index
0.55 0.5 0.45 0.4 0.35 0.3 0.25 0.2 0.15 0.1 0.05
0 20 40 60 80 100 120 140 160 180 200
Dispersion of Market Shares
0.035 0.03 0.025 0.02 0.015 0.01 0.005 0
0 20 40 60 80 100 120 140 160 180 200
Labour Productivity
1.3 1.2 1.1 1 0.9 0.8 0.7 0.6 0.5 0.4 0.3
0 20 40 60 80 100 120 140 160 180 200

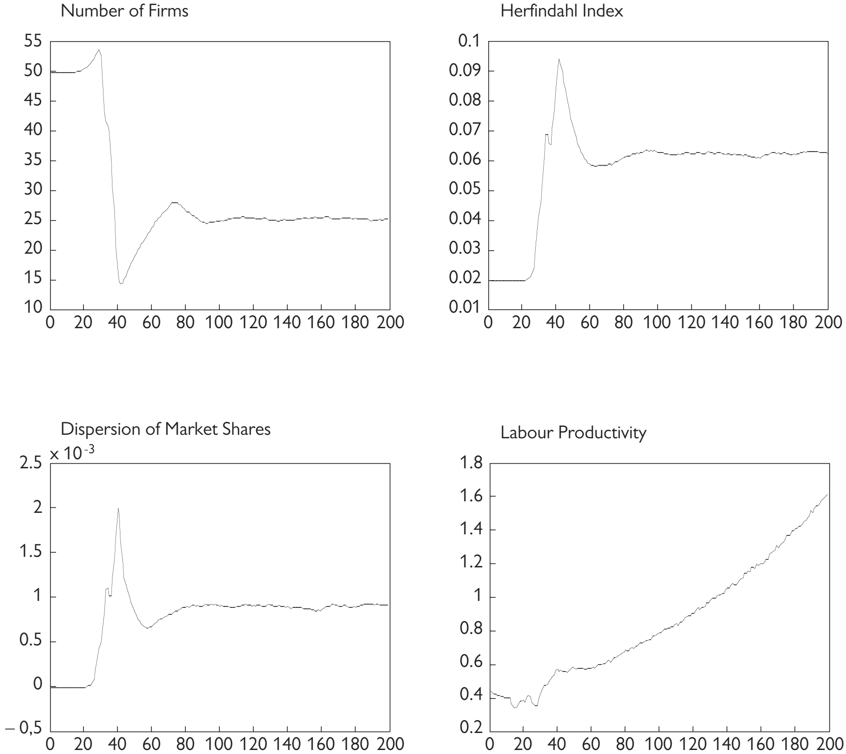
3.


Number of Firms
25 20 15 10 5 0
0 20 40 60 80 100 120 140 160 180 200
Labour Productivity
1.6 1.4 1.2 1 0.8 0.6 0.4 0.2
0 20 40 60 80 100 120 140 160 180 200

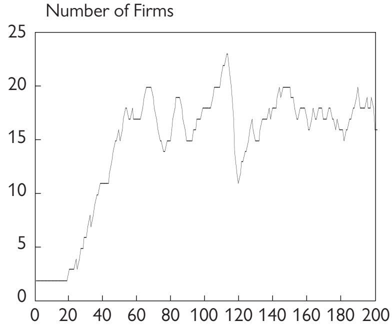
4.


Number of Firms
22 20 18 16 14 12 10 8 6 4 2
0 10 20 30 40 50 60 70 80 90

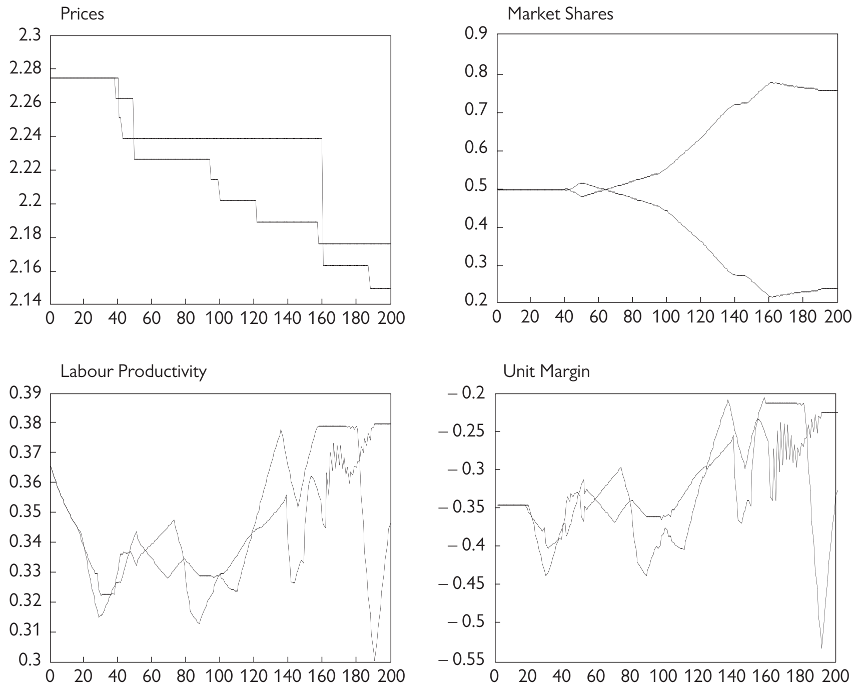
5.


Number of Firms
55
50
45
40
35
30
25
20
15
10
0 20 40 60 80 100 120 140 160 180 200
Herfindahl Index
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0 20 40 60 80 100 120 140 160 180 200
Dispersion of Market Shares
x 10-3
2.5
2
1.5
1
0.5
0
– 0,5
0 20 40 60 80 100 120 140 160 180 200
Labour Productivity
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0 20 40 60 80 100 120 140 160 180 200

6.


Number of Firms
25
20
15
10
5
0
0 20 40 60 80 100 120 140 160 180 200

7.

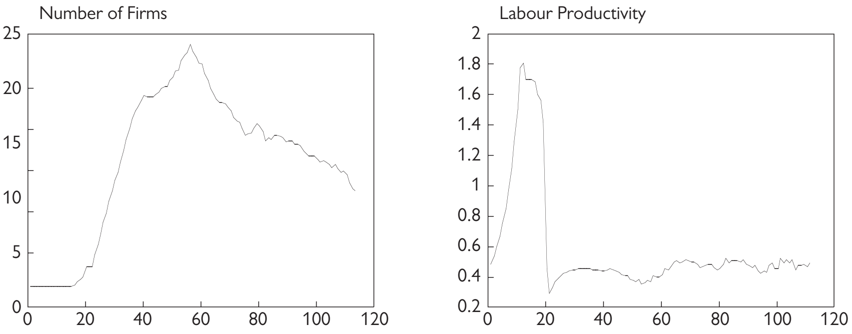


simultaneously results in a relatively strong instability in market share, which is associated with an increase in the concentration index. Costs and unit margins fluctuate strongly. There are actually no productivity gains from innovations (figures 7).

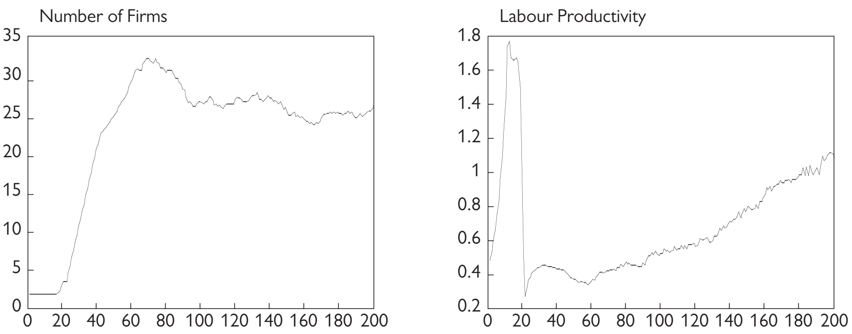
However, when prices evolve together with current costs and hence are volatile, despite the existence of resource constraints, strong turbulence occurs which prevent the economy from being viable. There is a shake out process that does not necessarily result in the stabilised market structure that would be associated with the capability of each firm to really capture productivity gains (figure 8). Nevertheless, within this latter price regime, in the case of monopolistic competition ($\beta < 1$), when the global market is segmented between customers that do not react to changes in firms' prices , the market structure is stabilised and productivity gains accrue. This is because market shares are much less sensitive to price gaps. Price fluctuations do not disturb the demand profile and hence the temporal structure of productive capacity (figure 9). A form of market power is beneficial.

To sum up. *Increasing returns*— obtained in a context of sequential competition where each firm at different moments of time introduce new

8.



9.



products belonging to the same general market— allow only a transitory competitive advantage. Several heterogeneous firms can coexist in the market, despite the existence of increasing returns, remaining differentiated not so much because they supply differentiated goods, but because they are at different stages in the production process life cycle. The latter situation can be defined as a dynamic equilibrium. This is a situation in which competition causes "the rate of investment in product development to rise or fall towards the level at which this investment yields only a normal return" (Richardson, 1998: 172). This is a situation in which the prices charged by firms reflect decreasing average costs so as to allow the benefits from innovation to also benefit consumers. This is also a situation in which *stability of markets shares* obtains: there are neither significant new entries nor significant exits from the market.

These considerations not only qualify as a dynamic equilibrium, but also represent the competitive conditions consistent with increasing returns.

5. Conclusion

What happens to the firms involved in innovation— what happens to their cost performance and market shares, and hence what happens to the market structure— has been looked at as a process sketched, step by step, by sequentially interacting disequilibria. What essentially matters is the deformation of the structure of productive capacity of the different firms involved, which will be amplified or dampened according to the nature of the co-ordination mechanisms that prevail. We tested the conjecture that the possibility of being able to take real advantage of innovations essentially depends on the ability of each firm to maintain a productive capacity structure that sustains a quasi-steady state. And this depends in turn on the working of the market coordination mechanism.

The availability of productive resources, and the constraints that these may impose on the production process, and the equilibrating (or disequilibrating) role played by price and wage regimes, are the essential elements of the co-ordination mechanism at work.

There is no *ex ante* optimal co-ordination mode. It all depends on how the ingredients mentioned above are combined along the way. And this depends in turn on the specific context within which co-ordination has to be carried out (initial number of incumbent firms, entry and exit conditions, and the like).

It follows that the success (or not) of the introduction of new technologies and the emergence and evolution of given market structures is not dependent on the properties of technology, but depends on the capacity to coordinate the activities of the various firms participating in the restructuring process, which results in a certain degree of *stability* in the market structure.

Thus, technological advances do not determine the dynamics of the number of firms. On the contrary, these are identified only once a stable market structure signals that viability conditions have been fulfilled. Nevertheless, different market structures can emerge from the same kind of innovation process, depending on the effective working of the coordination mechanism.

The focus on the coordination of innovation seen as an essentially economic process reveals that there is no 'new economy' problem related to the specific character of particular technologies, namely, ICTs. The true reason why these are seen as a major factor of growth is that their supposed flexibility is believed to remove obstacles to the working of the market and eliminate the possibility of market failure (such as the existence of increasing returns or the choice of non optimal scales of production), thus making possible to establish full competition. We have shown, in contrast, that the more we let the market operate in a sense close to Walrasian equilibrium (by assuming full price and wage flexibility, free entry, and the like) the less likely that it will be that viable innovation processes will emerge and the benefits of technology will be reaped.

Finally, it is worth mentioning that these results corroborate those in Arrow's study devoted to a better understanding of the behaviour of the economy in conditions of disequilibrium.

In any state of disequilibrium, i.e. any situation in which supply does not equal demand, … the economy will show evidences of monopoly and monopsony. These evidences will be the more intense, the greater the disequilibrium… [This] suggests that the measurement of competitiveness by the concentration ratio has to be interpreted carefully. A degree of concentration which would be perfectly compatible with a reasonable degree of competition if the market were in equilibrium might easily fail to be so compatible in the event of serious inequality between supply and demand. (Arrow, 1959: 48-49)

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