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THE RISE AND FALL OF INDUSTRIAL CLUSTERS: TECHNOLOGY AND THE LIFE CYCLE OF REGIONS [a,b]

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ABSTRACT: When a major technological innovation spreads out in both high-tech and middle/low-tech industries, new clusters appear, develop and grow at the expenses of “older” historical industrial sites. The literature has, under various labels, recognised three main stages of cluster development: an initial stage sparked by an initial exogenous, shock; a second stage driven by Marshall’s (1920) agglomeration economies (labour market pooling, supply of intermediate goods and services and knowledge spillovers); a third stage in which the cluster either achieves a sectoral leadership or declines. The paper shows how different clusters’ evolution (often told as separated stories) are part of a wider picture in which technological and spatial interactions between emerging and declining clusters play a decisive role. A final section draws some policy suggestions for public authorities and regional planners dealing with the development of an innovative cluster.

Keywords: Industrial clusters, technological dynamics, agglomeration economies and diseconomies.
JEL Classification : O33, R3, R11.

RESUMEN: Cuando una gran innovación tecnológica se extiende en las industrias de cualquier nivel de tecnificación, nuevos clusters aparecen, se desarrollan y crecen a costa de formas industriales más antiguas. La literatura ha reconocido, bajo diversas denominaciones, tres estados principales en el desarrollo de los clusters: un estado inicial marcado por un primer shock exógeno; un segundo estado influenciado por las economías de aglomeración de Marshall (1920) (mercado laboral único, suministro de bienes y servicios intermedios y externalidades por el lado del conocimiento); y un tercer estado en el cual los clusters bien acaban liderando un sector bien se deterioran. El trabajo muestra cómo la evolución de los diferentes clusters (con frecuencia explicado como cuestiones separadas) son parte de un marco más amplio en el cual las interacciones espaciales y tecnológicas entre clusters emergentes y en declive juegan un papel decisivo. Una sección final traza alguna sugerencia política para autoridades públicas regionales que tengan que tratar con el desarrollo de un cluster innovador.

Palabras clave: Clusters industriales, dinámica tecnológica, economías y deseconomías de aglomeración.
Clasificación JEL: O33, R3, R11.

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I will tell the story as I go along of small cities no less than of great. Most of those which were great once are small today; and those which in my own lifetime have growth to greatness were small enough in the old days”

Herodotus (440 B.C.), *The History*, quoted in J. Jacobs (1969)

As new industries emerge, firms in those industries may then be faced with location decision of the following sort. Should they locate in an old cluster, where they have little commonality with incumbents where the established infrastructure is dated, and where congestion costs are still relatively high though admittedly declining? Or they do locate in a new cluster where the incumbents, though new and small, are generating the sorts of spillovers that attract entrants and are based in more relevant industries, and where the infrastructure is better?

G.M.P. Swann et Al. (1992), *The Dynamics of Industrial Clusters*, Oxford University Press, Oxford.

“Semiconductor manufacture began in Phoenix (Motorola), and Dallas (Texas Instruments), at about the same time as Shockley Laboratories and Fairchild Semiconductor were established in Santa Clara County in the late 1950s. Aircraft production began in Wichita (Cessna), Buffalo (Curtis), Seattle (Boeing), Los Angeles (Martin, Lockheed, Douglas), as well as in Baltimore and Bridgeport. Farm machinery started up in Stockton (Holt), San Leandro (Holt), and San José (FMC), California, as well as in the Midwest. Yet Santa Clara County, Los Angeles and Illinois become the overwhelming centers of attraction in semiconductors, aircraft and farm machinery, respectively. Only these places developed large complexes of firms producing intermediate inputs as well as final outputs”.

M. Storper - R. Walker (1989), *The Capitalist Imperative*, *Territory, Technology and Industrial Growth*, Basil Blackwell, New York.

1. Introduction

When a major technological innovation spreads out in both high-tech and middle/low-tech industries, new clusters appear and - if the innovation is commercially successful - they often develop and grow at the expenses of “older” historical industrial sites. The names of successful areas and products become inseparable (i.e. Detroit and the standardised car in the early 1900s, Santa Clara County/Silicon Valley and the semiconductors in the mid-1950s, Boston/Route 128 and the minicomputer in the early 1980s, etc.).

What happen to new cluster when they become "old" is a matter of interactions between agglomeration economies vs. diseconomies on the one hand and the rate of incremental vs. radical innovations on the other. Thus technological and regional dynamics go hand in hand and they mutually determine each another in a complex web of circular cumulative causation (with both positive and negative feed-backs).

The literature has, under various labels, recognised three main stages of cluster development:

- an initial stage in which the development is sparked by an initial, often exogenous, shock (and sustained by the involuntary informational spillover provided by early entrants about the profitability of the location);
- a second stage in which the drivers of Marshall's (1920) agglomeration economies (labour market pooling, supply of intermediate goods and services and knowledge spillovers) play a crucial role in sustaining endogenously the growth and the structural transformation of the cluster through start-ups and spin-offs;
- a third stage in which either the cluster achieves a national/international leadership in a given sector/technology and becomes resilient, (i.e. able to withstand technological shocks and economic recessions[1]) or the cluster declines (both socially and economically) generating – within different institutional frameworks – huge migration outflows or mass unemployment.

The paper intends to develop from Brezis and Krugman (1997) in order to show how different clusters' evolution (often told as separated stories) are part of a wider picture in which technological and spatial interactions between emerging and declining clusters play a decisive role. The whole process can be easily described within a population ecology theoretical framework where both technological dynamics within the cluster and spatial interactions between clusters determine the "life cycle" of a cluster. The paper makes a parsimonious use of formal analysis (diagrams and simulations) in order

[1] Becoming what Markusen (1996) calls a "sticky place".

to illustrate the different possible evolutions of the dynamical system composed by two clusters. A final section draws some policy suggestions for public authorities and regional planners dealing with the development of an innovative cluster.

2. The development of a cluster: a selected survey

Throughout the paper, the development of an industrial cluster is modelled as a (non-monotonic, unimodal) function of the "industrial mass" already located there. This intuition (which will be analytically dealt in section 2) – which corresponds to a well known and recognised stylised fact of the development of industrial clusters – may be derived from alternative a/o complementary "explanations" which involve different coordination mechanisms, agents' behaviours and believes, etc.

- **Spin-off and imitation:** new firms within a cluster are often started by former employees of pre-existing firms or originated by local people imitating successful entrepreneurs (through a sort of "contagion" process). Both phenomena are proportional to the incumbent mass; however, while the spin-off story alone will generate an exponential "explosive" development (if not balanced by some counteracting force or controlled by a variable "birth" rate), the imitation story – in a population of a given size – will generate an S-shaped development process since the imitation process is proportional to the product of the number of potential entrepreneurs and of actual ones (Anton and Yao, 1995; Klepper and Sleeper, 2002; Dahl, Pedersen and Dalum, 2003).

- **Signalling (a):** in an uncertain environment, with strong information asymmetries between insiders and outsiders, the number of firms (belonging to the same industry) already located in the cluster signals the profitability of the location (due to the quality of the workforce, the availability of intermediate inputs, the general "business climate") to potential entrants (Pascall and McCall, 1980). This informational forward spillover mechanism works even in absence of agglomeration economies and may generate "informational cascades" (Bikhchandani, Hirshleifer and Welch, 1992; Hirshleifer, 1993), "herd behaviour" (Banjeree, 1992) and, with strong relocation costs", lock-in phenomena. An interesting point is made by Choi (1997) who shows that the presence of informational externalities and spillovers may also work backward, i.e. the herd behaviour of subsequent entrants influences the initial location decision, so that a bias against new locations can be created by the "fear of being stranded" (Choi, 1997, p. 408)[2].

- **Signalling (b):** by choosing to locate into a well established (i.e. larger) cluster, a firm signals its quality to potential customers by showing its ability to survive to harm's length competition in the inputs (i.e. skilled labour, venture capital/bank funding, land, etc.) and in the output (especially if sold to other local firms as intermediate input) markets. This point is highlighted by Vettas (1999) who shows that – in an Hotelling-type model with both vertical and horizontal product differentiation – spatial agglomeration may be used as a high-quality signal by firms acting in an incomplete information environment. Thus choosing an established cluster is a quality signalling and reputation building strategy which, with imperfect ex-ante information on its own ability and risk prone entrepreneurs, may even generate excessive clustering[3]. Once the cluster becomes sufficiently large[4], the fear of excessive competition reduce the entry rate thus stabilising the size of the cluster (Nocke, 2003).

- **Information diffusion[5]:** information (news or rumours) about a new profitable location for a given type of firm may be diffused in a given population of potential entrants and entrepreneurs through an epidemic model (Grilliches, 1957; Bass, 1969). If one assumes that information diffuses through contacts, and that these contacts are random, then at any moment of time the rate of diffusion of an innovation is proportional to both the fraction of actual users and the fraction of potential users. Alternative interpretations assume that, at any moment in time, there is perfect information on the existence and nature of the new cluster. However each potential entrepreneur/existing firm, before deciding whether or not to locate (or re-

[2] A similar behaviour, but in the context of complete information, has been studied by Farrel and Saloner (1985 and 1987) under the name of "penguin effect" from the behaviour of a flock of penguins gathered "on the edges of ice floes, each trying to jostle the other in first, because although all are hungry for fish, each fears there may be a predator lurking nearby" (Farrel and Saloner, 1987, p. 14).

[3] A similar result, applied to the clustering of scientist on a minority of "hot topics", is obtained by Rocco (2003).

[4] The toughness of price competition is positively related to the size of the cluster, hence in larger markets opportunities are greater (more consumers, more suppliers) but price-cost margins are narrower. More talented (i.e. efficient) entrepreneurs benefit relatively more from larger markets (Nocke, 2003, p. 4).

[5] All the original references quoted in this explanation deal with technological diffusion. The interpretation within the location analysis framework has been proposed in Maggioni (2002).

locate), must compare the benefits and the costs of location. In "rank effects" models (David, 1969; Ireland and Stoneman 1986) it is assumed that the heterogeneity of potential entrants causes different returns from entry and, indirectly, different dates of location. In the "stock effects" models (Reinganum 1981; Quirmbach 1986) the benefits from location depend on the existence of agglomeration economies and diseconomies. In the "order effects" (Ireland and Stoneman, 1985) models it is argued that location benefits to a firm depends on its position on the order of entry (on the basis of a "first come, better served" criterion).

- **Anchor tenant:** originally conceived in the real estate economics literature, this label has been imported in the high-tech clusters literature by Feldman (2002) and refers to the fact that the existence of a large established industrial firm creates externalities that "contribute to benefits of agglomeration" (Feldman, 2002, p. 14). Thus the number of new start-up firms (and their internal growth) is therefore positively related to the number of anchor tenants in the cluster (due to knowledge spillovers, specialised inputs procurements and user innovation networks). This process is empirically confirmed and theoretically modelled by Rauch (1993) with specific reference to "artificial" clusters where developers play an active role in building the membership of an industrial park through a carefully designed strategy of discriminatory land pricing[6]. The location of large firms (either spontaneous or sponsored) may therefore act as catalyst of the clustering process in the early stages of an industry, when uncertainty is strong and no obvious location has still emerged.

- **Leader–suppliers relationship:** Thoroughly described in the Italian literature on industrial districts (Belussi, 1988; Garofoli, 1991; Bramanti and Maggioni, 1997; Paniccia, 1998), this explanation focuses on the composite (both synergetic and competitive) relationship existing between a small number of large leading and innovative firms – acting as organizers and coordinators of the activity of the whole districts – and a large number of imitative small firms (often craftsmen) which act mainly, but not exclusively, as sub-contractors. The relationship between the development of these two populations of firms within the same industrial district is an example of complex co-evolution in which pecuniary externalities and

[6] This strategy is based on the subsidisation of early (or "seed") tenant (usually nationally prominent firms) while "later tenants are paying for the privilege of benefiting from economies of agglomeration as firms accumulate in the park, allowing the developers to recoup the cost they incurred in subsidising early tenants" (Rauch, 1993, p. 858).

competitive dynamics play different roles at different times (Folloni and Maggioni, 1994). Suppliers like to be in a district with a sufficient number of leaders because of the higher price they can get for their product and because of the “insurance” they derive from the plurality of buyers but they suffer to be in a district with many leaders because they fear their competition on inputs (land, labour, credit). Leaders like to be in a district with a sufficient number of supplier because of the lower price they can pay for their intermediate inputs but they suffer to be in a district with too many sub-contractors because of the limited knowledge spillovers and the reduction in the appropriability of their innovation.

- **Institutional processes and social legitimacy**: originally conceived in the organisational ecology literature (Carrol, 1988; Hannan and Freeman, 1989, Staber, 1997) this explanation refers to the fact that density affects founding rates of “organisational population” (for our purposes a given type of firm) through institutional processes. “when numbers are small, those who attempt to create a form must fight for legitimacy. (…) Once a sufficient number of instance of the form exist, the need for justification (and thus the cost of organizing) declines. Other things being equal, legitimation of a form increases the founding rate of population using the form. If legitimacy increases with the prevalence of the form in the society, then legitimation processes produce positive density dependence in founding rates” Hannan and Freeman (1988, p. 21). If knowledge is assumed to be local, then the natural consequence of such a process is spatial clustering. The same process does not produce an unbound growth because is counterbalanced by competition: “the main source of negative density dependence is competition within and between populations. The more abundant are competitors, the smaller the potential gains from founding an organization at a given level of demand for product and services” (ibidem).

- **Agglomeration economies and diseconomies:** originally conceived by Marshall (1920) and later rediscovered – firstly by the regional and urban economics literature (Isard, 1956; Henderson 1977) and secondly within the “new economic geography framework by Krugman (1991) – this explanation highlights that each new entrant increases the locational benefits to incumbents (because of the existence of labour market pool, intermediate inputs pool, technological externalities and knowledge spillovers) only up to a point, then it decreases them when competition and congestion prevail. Both locational costs and gross benefits are non monotonic functions of the local industrial mass[7]. As far as costs are concerned, they are U-shaped due to the classical combination of a decreasing average fixed cost schedule and an increasing variable fixed cost schedule; as far as gross benefits are concerned they have an inverted U shape due to the interaction of agglomeration economies and congestion phenomena over a limited amount of land and infrastructures[8]. Net locational benefits are described therefore by an inverted U-shape function of the number of located firms which is often quoted as the indirect microeconomic foundation of an S-shaped development path of the cluster.**Locational benefits and costs and the development of an industrial clusterç**

Firms decide to settle in a cluster on the basis of the expected profitability of being located there. This profitability depends on net locational benefits - obtained as the difference between gross locational benefits and costs - which, in turn, are based on both observable and unobservable elements.

For simplicity it can be assumed that, in an uncertain world - with limited information regarding local costs and revenues available to the outsiders - profitability expectations for any particular location will be based solely on the number of firms already located there (the number of previous locations being the only observable variable).

Let us assume, as in Arthur (1988 and 1990), that locational gross benefits B_{fq} for firm f locating in cluster q are composed of geographical and agglomeration benefits[9] and let us model them as in Maggioni (2002).

[7] Similar arguments support the existence of a unique optimal dimension of the city (Henderson, 1077; Richardson 1978).

[8] Even if no physical border exist to the expansion of the cluster one must take into account the existence of organizational “minimum efficient scale”.

[9] For analytical convenience I split locational benefits in two classes: geographical and agglomeration benefits. The first class refers to those components which are unaffected by the number of incumbents; while the second refers to those components which depend on the number of incumbents. By adopting this formulation, however, I do not intend to state that agglomeration benefits refer only to spillovers of scientific and technological knowledge and know-how. On the contrary I am convinced that relevant agglomeration benefits derive also from external economies of scale in the use of local resources. The same variable (i.e. labour productivity) has a fixed geographical component, which depends on the quality of local workers, and a variable agglomerative component which depends on the number of firms already located in the cluster.

Geographical benefits G_{fq} depend on the intrinsic features of the site (such as the quality of local factors of production: capital k_q and labour l_q; the efficiency of the local network of specialised suppliers and business service firms s_q; and the quality of urban and industrial infrastructures u_q). Agglomeration benefits $A_{fq}\left(n_q\right)$ are a concave non monotonic function of the number of incumbents (i.e. firms already established in cluster *q*) n_q. Thus:

$$B_{fq} = G_{fq}\left(k_q, l_q, s_q, u_q\right) + A_{fq}(n_q) \quad (1)$$

The assumption of concavity and non monotonicity in A_q implies that, as the number of firms located in cluster *q* increases, gross benefits firstly increase because of agglomeration economies (due to productive specialisation; scientific, technical and commercial spillovers; reduction in both transport and transaction costs, increases in the quality of the local pool of skilled labour force and in the efficiency of the local credit market); then decrease when congestion more than compensates for agglomeration economies.

Locational costs c_{fq}, symmetrically, include two components: geographical costs g_{fq} (reflecting the cost structure of the cluster in terms of locally prevailing wage w_q and interest rate r_q; average price of business services d_q; and level of land rent and taxation t_q), and agglomeration costs a_q, which are assumed to be a convex non monotonic function of the number of regional incumbents n_q.

$$c_{fq} = g_{fq}\left(w_q, r_q, d_q, t_q\right) + a_{fq}(n_q) \quad (2)$$

The assumption of convexity and non monotonicity in a_q implies that, as the number of firms in cluster *q* increases, locational costs initially decrease until some "optimal" number of users for a given set of urban, industrial and environmental infrastructures and resources is reached. Then they increase due to the competition, between a larger number of firms, for a limited pool of local inputs (i.e. capital, labour, business services, land and public infrastructures) which raises their prices[10].

Net locational benefits can now be calculated as the difference between equations (1) and (2).

$$N_{fq} = B_{fq} - c_{fq} = H_{fq}\left(w_q, r_q, d_q, t_q, k_q, l_q, s_q, u_q\right) + h_{fq}\left(n_q\right) \tag{3a}$$

Assuming that the geographical benefits and costs do not change overtime, if we focus the analysis of the location process on the dynamics of the interactions between the level of available locational benefits, what becomes relevant for describing firms' location decisions is just the net benefit function N_{fq} in the incumbents' space. I can therefore summarise the geographic components H_{fq} with a parameter α_q, which vertically shifts the locational net benefits function, and write the following expression:

$$N_{fq} = B_{fq} - c_{fq} = \alpha_q + h_{fq}\left(n_q\right) \tag{3b}$$

It easy to see that the locational net benefits function (3b) is always concave, since N_{fq} is equal to the difference between a concave function $B_{fq}\left(n_q\right)$ and a convex one $c_{fq}\left(n_q\right)$. In other words, each marginal firm, which enters the cluster, increases the average profitability of locating in the cluster only up to a threshold. After that point, any new entrant lowers the average net benefits available to each resident firm and new entrant[11].

This formulation recalls some general results, obtained in the industrial location and urban/regional economics literature (Weber, 1929; Isard, 1956; Richardson, 1978; Papageorgiou, 1979; Tauchen and Witte, 1983; Miyao and Kanemoto, 1987), which

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[10] An alternative explanation for the convexity of the locational costs function for firm *f* runs as follows: the locational costs function is composed by a "fixed" and a "variable" component. The fixed part of the costs (geographic costs) decreases as the number of entrants increase; while the variable part increases (because of competition) as the number of entrants increase. The combination of these two effects produce an U-shaped (convex) cost curve as the interaction between fixed and variable costs of production in standard microeconomics textbooks. A symmetric reasoning may also explain the inverted U-shaped benefits function. This interpretation is surely more realistic than the one used in the paper, however it is not as theoretically efficient as the other one since both components become dependent on the number of incumbents.

[11] However, as it is made graphically evident in figure 1, because of the inverse U shape of the marginal benefits function, there is a range, within the number of incumbents, where marginal net benefits are already decreasing, but still higher than average ones, and average net benefits are still increasing.

show the existence of an optimal dimension of a given spatial agglomeration of firms and/or households because of the concavity of the various benefits functions.

With the help of figure 1 (which shows both marginal and average locational costs and locational benefits schedules), I want firstly to highlight the existence of several "optimal" sizes[12] of the region, and secondly to show how K_q is endogenously determined by the structure of locational benefits and costs functions.

Let us consider the costs and benefits derived from entering a region; for the sake of simplicity let firms outside the region experience zero locational benefits[13] and assume that geographical benefits are set to zero. Firms are assumed, for the moment, to be locationally identical (i.e. the agglomeration economies and diseconomies, locational benefits and costs are the same for every firm). Therefore I can study the behaviour of a representative firm *f* and analyse its average net benefits function[14].

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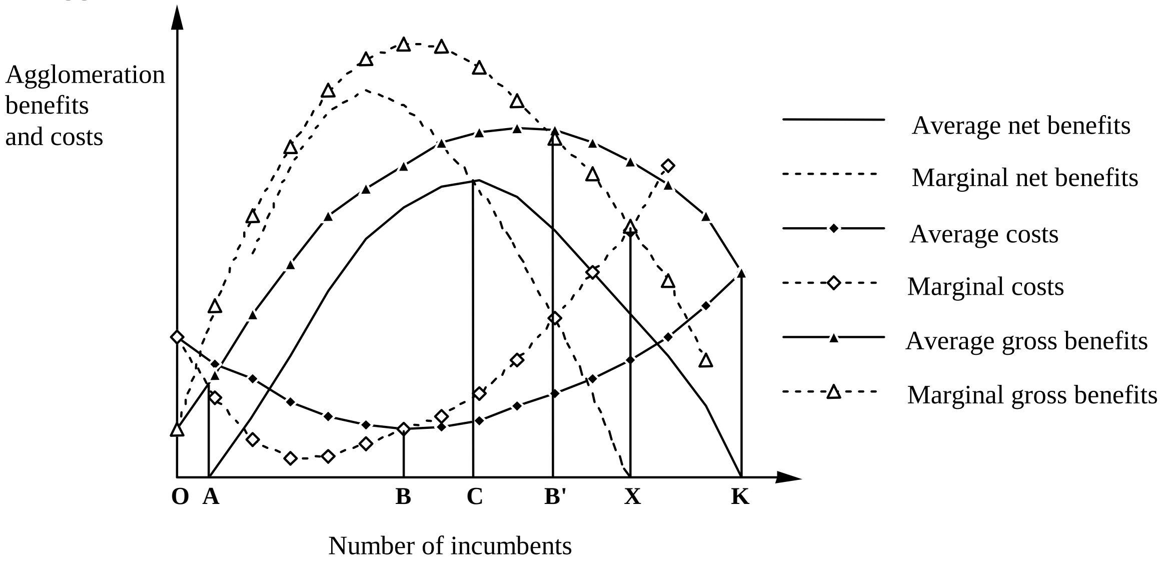
[12] Throughout the paper the "industrial size" or "economic mass" of a region is approximated by the number of located firms. This index can easily be substituted by a more realistic proxy of firms' dimension (such as employment or sales). However the number of firms has an obvious advantage in its simplicity and is the best indicator when the inter-firms relationships at study (i.e. knowledge spillovers) are independent of firm's size.

[13] However, this assumption can easily be relaxed by assigning the locational benefits of the cluster a value equal to the difference between the locational benefits available outside and inside the cluster.

[14] By considering average functions I indirectly assume that some market mechanisms is at work in the cluster and makes both benefits and costs equal for each incumbent.

Figure 1
Agglomeration costs and benefits for incumbents and critical sizes of a cluster



A is the minimal sustainable dimension of the cluster (i.e. where agglomeration net benefits start to be positive and, consequently, $\frac{dn_q(t)}{dt} > 0$). Prior to **A** no firm will spontaneously enter the region (because agglomeration benefits are negative). **A** can be called the "critical mass" of the region. **A** can be reached only by a group of co-ordinated firms entering together, or by direct intervention of a public authority aimed at subsidising entries until *n(t)* = **A**.

B is the dimension where average agglomeration costs are minimum. **B'** is the cluster dimension which maximises gross average agglomeration benefits. **B** and **B'** underline the importance of analysing both costs and benefits of location to avoid harmful misrepresentation of the economic reality, as in some early contributions of location theory[15]. Obviously, it could also be the case that **B'** < **B**.

C gives the maximum per firm net benefits (i.e. average net benefits). Up to **C** every new entrant increases (by its very entry) the average benefits of all incumbents; after **C** the average benefits decrease. **C** is therefore the optimal size of cluster for incumbent firms; however, it is neither the social efficient outcome (given that marginal benefits are still greater than marginal costs) nor the maximum possible dimension (average benefits are still positive). At **C**, several firms outside the region might still want to

[15] Here the reference is to the debate betweenthe "least cost" and the "demand side" approaches.

enter, while firms already in the region would like to deter further entries. Here there is a contrast between incumbents, outsiders and public authorities, each of them with a different view of what is the optimal outcome.

X is the economically efficient (i.e. social optimum) dimension. At **X** marginal costs equal marginal benefits, therefore the total benefits (number of firms times *per capita* benefits) are maximised. However, as the average benefits at **X** are still positive, some outsiders would still like to enter. Such entries would reduce the total amount of benefits available to incumbents.

K is the maximum dimension of the region (in terms of economic mass) since $B_{fq} = c_{fq}$. From **K** onwards no more net entry is deserved because, after this point, average benefits are negative and therefore there are no incentives to enter. However, new entries are still possible but these would be at the expense of some incumbents who would be driven out of the cluster[16].

4. The "life cycle" of clusters: an ecological model

The simplest growth model for an industrial cluster *q* - which stresses the relevance of firms spatial interactions - can be expressed in the following format: "the rate of growth of the industrial mass equals the product of the individual firm's contribution[17] to the regional population's growth and the number of firms already in the cluster" (Maggioni, 1993, 1999).

If only positive feedbacks mechanism (such as spin-off, agglomeration economies and knowledge spillovers) are taken into account (and these are assumed to be constant), then each individual firm's contribution to the level of average locational benefits and, consequently, to the growth of cluster *q*, would be equal to a constant r_q. In this case cluster industrial growth would follow an "explosive" exponential path[18], formally:

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[16] After **K** new entries thus support a turnover process without causing relevant changes to the equilibrium level.

[17] In terms of changes in the average locational net benefits, due to the interaction of agglomeration economies and diseconomies.

[18] The higher the cluster's growth rate (r_q), the faster the growth process.

$$\frac{dn_q}{dt} = \dot{n}_q = r_q \, n_q(t) \qquad (4a)$$

Equation (4a) can also be solved for $n_q(t)$ as function of the exogenous initial industrial mass of the cluster $n_q(0)$:

$$n_q(t) = e^{r_q t} \, n_q(0) \qquad (4b)$$

On the other hand, if negative feedbacks (such as congestion and competition effects, or epidemic dynamics) are included, then some modifications to this simple model are required to allow for some "density dependent" factors to progressively depress the level of locational benefits and to slow down the process of industrial growth of the cluster. A simple dynamic model, which takes into account these features is the logistic equation[19], which can be written as (5a)

$$\frac{dn_q}{dt} = \dot{n} = r_q n_q(t)\left(1 - \frac{n_q(t)}{K_q}\right) \qquad (5a)$$

where r_q is the incipient (or maximum) rate of increase and $K_q = \lim_{t \to \infty} n_q(t)$, is called the cluster "equilibrium" level[20].

Integrating equation (5a) and solving it for $n_q(t)$ as function of the exogenous initial industrial mass of the cluster $n_q(0)$ one obtains (5b):

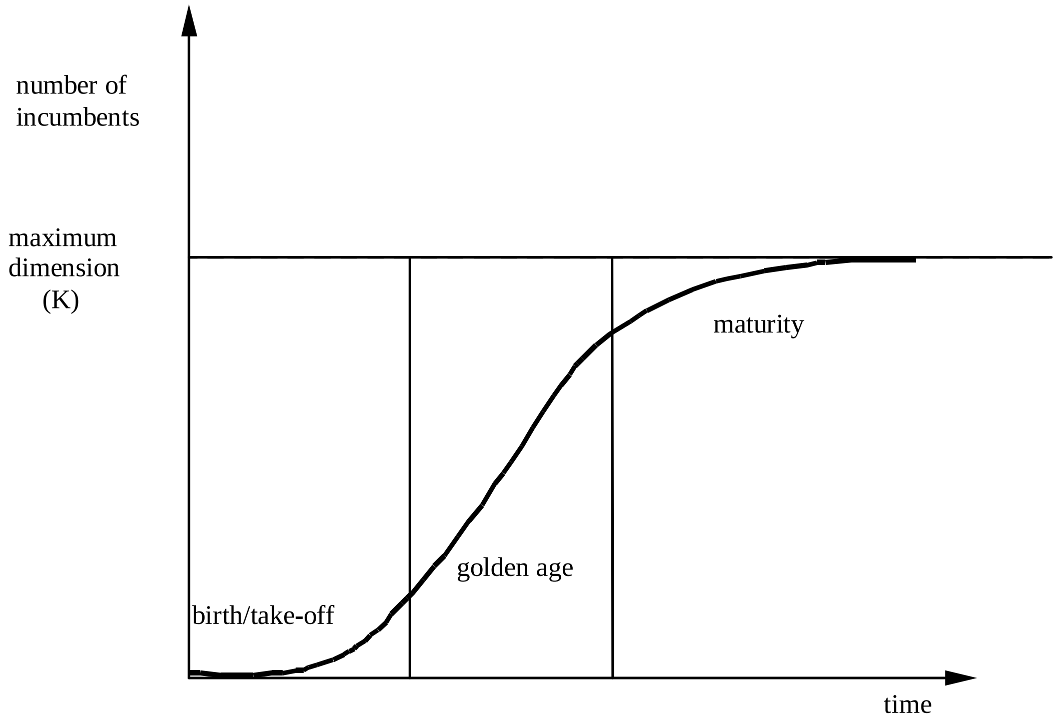
$$n_q(t) = \frac{K_q n_q(0) e^{r_q t}}{K_q + n_q(0)\left(e^{r_q t} - 1\right)} \qquad (5b)$$

Plotting $n_q(t)$ against time yields an S-shaped curve due to the counteracting roles played by r_q and K_q.

19 The logistic equation - firstly developed by Verhulst (1845) and Pearl and Reed (1920) for demographic studies, then adopted by the ecological literature since Lotka (1925) - "is the simplest model containing negative density dependence interaction. Further, it is the first two terms in a power series expansion of a more general growth model where the growth is a function of the actual size of the population" (Dendrinos and Mullally, 1985, p. 38).

20 Or, in the original ecological jargon, the *carrying capacity*, defined as: "a measure of the amount of renewable resources in the environment in units of the number of organisms these resources can support" (Roughgarden, 1979, p. 305).

Figure 2
The development of an industrial cluster (in isolation)



Source: Maggioni (2002a)

When the cluster is small (i.e. $n_q(t)$ is close to zero) the term in brackets in equation (5a) is close to one (hence the logistic equation approximately describes an exponential growth path); but as $n_q(t)$ approaches K_q, the term in brackets tends to zero, driving the growth rate to zero and terminating the entry process.

Both K_q and r_q play a major role in shaping a logistic growth path: the greater is r_q the steeper is the S shaped curve, the larger K_q the higher the ceiling level of the function (and the equilibrium size of the cluster).

r_q is the cluster's incipient (or intrinsic) growth rate. In the ecological literature it is calculated as the difference between the birth and mortality rates of a population. This observation can be translated into the economic framework when net entry (and consequently the intrinsic rate of industrial growth of a cluster) is calculated as the difference between total entries (or start-ups) and exits (or bankruptcies) in the period considered. The same value of r_q can therefore correspond to two very different situations: a steady growing cluster where few new firms enter and no one exits, and a perturbed cluster where a high "birth" rate is almost compensated for by a high "death" rate. Hence r_q is a composite index that describes the cluster growth "potential" and the probability that firms, once entered, survive in the cluster.

K_q defines the regional industrial carrying capacity: the maximum number of profitable firms the cluster can sustain in isolation (i.e. when inter-regional interaction are not considered). K_q will depend upon:

i) the finite quantity of geographical benefits (which is related to the limited availability of local "resources" such as: labour, capital, land, intermediate inputs and infrastructures);

ii) the decreasing part of the agglomeration benefits function (which depends on the strategic interactions between firms: competition, congestion and lobbying of incumbents).

K_q is therefore determined by the relationship between the amount of resources (inputs) available in the cluster and the (technical and organizational) efficiency of incumbents in the use of these resources. Therefore in the long run K_q may change as result of the inflow of additional skilled workers, the provision of new advanced public infrastructure, the diffusion of (technical, organisational, etc.) innovations.

For a given cluster *q* and a given population of M_q outsider firms[21], therefore, I assume that there is an equilibrium level $K_q \leq M_q$ acting as an upper limit to the cluster's growth. In each period *t*, the number of entries therefore depends both on the actual number of potential entrants $K_q - n_q(t)$ (i.e. the number of outsider firms which can enter the cluster in time *t* and still make profits) and on the number of firms already located there $n_q(t)$. K_q and $n_q(t)$ in fact determine the level of average locational net benefits available to incumbent firms in each period of time.

In this first formulation, the number of located firms directly generates (through agglomeration dynamics) the level of locational benefits; since the entry rate is assumed to be proportional to the level of locational benefits, it also indirectly determines the location of new firms into the cluster.

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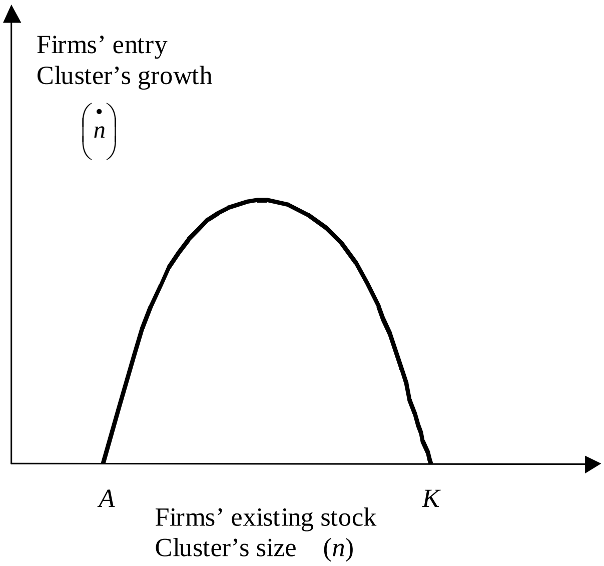
[21] Composed of two main categories: firms already established outside the cluster and potential entrepreneurs inside the cluster looking for the right moment to start their own business.

Such a formulation of the location process is very simple but can be used to empirically estimate key parameters of the location path of different clusters[22]. These estimated parameter could also be used as dependent variables in cross-section analyses in order to assess the influence of different factors on the level of the intrinsic growth rate of a cluster or on its maximum dimension.

One can plot the original formulation of expression (5a), i.e. a quadratic relation between firms formation (or entry) and the stock of firms already located (operating) in the cluster, as in figure 3:

Figure 3

The development of an industrial cluster (stock-flows relation).



Source: adapted from Maggioni, 2002b

Figure 3 has the advantages of showing two crucial dimension of an industrial cluster: *A*, the critical mass, i.e. the minimum dimension for a self-sustaining cluster and *K*, the carrying capacity (K_q), i.e. the maximum number of profitable firms the cluster can sustain in isolation due to the limited availability of local "resources" such as: labour, capital, land, and infrastructures and to the existence of strategic interactions (competition, congestion and lobbying of incumbents) between firms already located in the cluster.

[22] Where the difference may refers to different industries in the same geographical site, or to different geographical sites in the same industry.

Here the individual firm's contribution to the cluster' growth (and the cluster growth rate) is highest at the beginning of the development process and decreases as a linear function of the cluster's population size:

$$\frac{\dot{n}_q}{n_q} = r_q - \frac{r_q}{K_q} n_q(t) \tag{6}$$

An alternative formulation of the relationship existing between firms' entry and firms' existing stock within an industrial cluster use a cubic version of the original logistic function as follows:

$$\dot{n}_q = r\, n_q^2(t)\left(1 - \frac{n_q(t)}{K}\right) \tag{7}$$

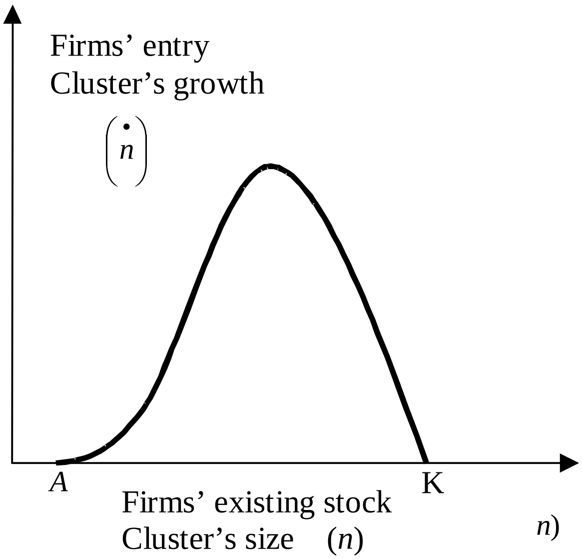
Expression (7) differs from expression (4a), because the individual firm's contribution to the cluster's growth (and the cluster growth rate) is a quadratic function of the cluster population size:

$$\frac{\dot{n}_q}{n_q} = r_q n_q - \frac{r_q}{K_q} n_q^2(t) \tag{8}$$

Such a formulation – where the growth rate of the cluster is limited both at the beginning (birth phase) and at the end (maturity) of the development path of the cluster – is useful to describe the development path of a cluster based on a new innovative technology, as will be shown in section 4.

While the time pattern of development is very similar to the situation depicted in figure 1, the relationship between the cluster's growth and the current dimension of the cluster is different and displays an initial convexity in the generally concave curve (as represented in figure 4).

Figure 4
The development of an innovative industrial cluster (stock-flows relation).



However both formulations can be criticised on a number of grounds. The main drawback refers to the "isolation hypothesis" which assumes that firms' location decisions are modelled as a dichotomous choice (there is only one possible site for location and the choice variable is just the timing of the entry) and no external factor influences the cluster's development.

Previous works by the author (Maggioni, 1993, 2000, 2002a, 2004b) extend this simple logistic equation to a system of differential equations in order to take into account a series of different inter-industry and inter-cluster bilateral interactions[23]. In this paper I will focus the attention on the interactions arising between an already developed cluster and a newly emerging one based on the rise of a new technology.

5. The interactions between established and emerging clusters

5.1. Technology and the life cycle of clusters

Let's assume as in section 2 that the development of an established cluster in isolation (cluster *i*) is described by equation (5a). Cluster *i* is specialised in the production of a well known product and uses an established technology. Now – following Brezis and

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[23] Such as competition, mutualism, commensalism, amensalism, predation.

Krugman (1997), with some crucial changes – let's assume that, after a certain time, τ, a new technology is introduced. The new technology may represent a new way to produce the same product (process innovation) or a new kind of the same product (product innovation). The critical hypotheses on the relationships between the two technologies are the following:

H.1. each technology follows a learning curve so that productivity is an increasing function of the cumulative experience within the cluster;

H.2. "past" experience is irrelevant (i.e. cumulative output produced by using the old technology has no effect on the new technology's learning curve);

H.3. the new technology is potentially superior (i.e. for a given amount of cumulative output the new technology is more productive or, in other words, learning effects are greater for the new technology);

H.4. despite this potential advantage the new technology is initially inferior to the old, given that no cumulative output exists for the new technology in any cluster;

H.5. while initially inferior to the old technology, the new technology is good enough that in a newly established cluster (of smaller size, thus with lower degree of competition and congestion) it allows higher locational benefits.

Firms choose which cluster to enter on the basis of the locational benefits available. The shape of locational benefits functions (and, consequently, the shape of the cluster's growth function) is crucially dependent on the technology used in the cluster. The growth of the established cluster is described by equation (5a): a "classical" logistic function (with an initially large, but linearly decreasing with the cluster's size, growth rate). The growth of the new cluster is described by equation (7), a "cubic" logistic function (with an "inverted U" growth rate, i.e. low for both very small and very large sizes of the cluster).

Firms can relocate from one cluster to another one and, by relocating, they absorb the "industrial atmosphere" (technological and knowledge spillovers, etc.) connected with the technology used locally. In particular, when firms relocate from the "old" cluster to the "new" one, they are able to exploit the knowledge spillovers, to poach already trained workers and thus they become able to use the new technology.

The results obtained by Brezis and Krugman may be replicated in this adapted framework and are rather sharp: “When the new technology becomes available, firms in the established center (cluster) do not adopt it, because given their experience they remain more productive with the old technology. A new smaller center (cluster) comes into being, however, because the new technology is good enough to compete with the old (in a newly established cluster). (…A)s the new technology matures through learning, both the new technology and the new city-region (cluster) that is based upon it, take over from the established region (cluster)” (Brezis and Krugman, 1987, p. 380)[24].

The story is based on the assumption that the key external economies that support the development of the cluster are learning effects associated with the geographical concentration of an industry in a cluster. As long as the technology undergoes “normal progress” (i.e. follows a technological trajectory) the interchange of knowledge within the established cluster will tend to preserve its leadership. When new technologies arrive that are discontinuous with those that came before (i.e. change the technological paradigm) existing industry concentration may be of little value and the result then is that new technologies tend to be exploited in new clusters that do not suffer the diseconomies associated with an established cluster.

The relation between the introduction of a technological innovation and the emergence of a new cluster is crucially dependent on H.3, i.e. on the fact that learning economies are greater for the new technology, and may be easily seen, in a two-periods framework,

[24] A somehow similar problem, but modelled in a different way (with two different, and complementary, types of workers), is studied by David and Rosenbloom (1990) which show that “the growth of employment at a rival location poses a dire threat to the prospects for continued growth (of the cluster) and may even replace growth with contraction” (David and Rosenbloom, 1990, p. 357). The results obtained by these authors are more complex than Krugman and Brezis’s ones. In particular David and Rosenbloom cannot model explicitly a case in which “two urban places were competing with each other for the same mobile work force. (In such a case), the contraction of the labour force at one locale would imply its further expansion at the other center. (…) It may be seen that the transfer of workers between the two cities will have two contradictory effects (…). On the one hand the expansion of the growing city’s labour force increases the size of the labour market externality at that location, on the other hand , the transfer of workers reduces the capital-labour ratio – and hence wages – in the growing city, while raising the capital-labour ratio in the other city. As a result, the effect of labour force growth at a rival location are no longer unambiguous” (ibid. p. 366-367).

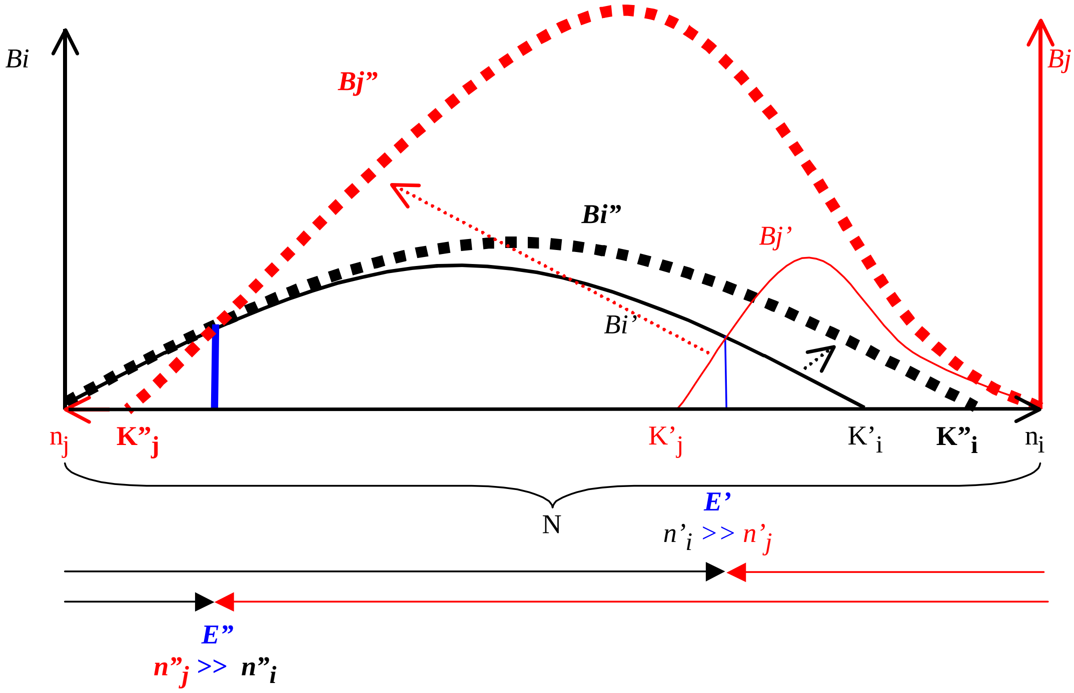
in figure 5, where the sizes of the clusters are measured along the same horizontal axes so that always $n_i + n_j = N$[25].

In the first period (denoted by') cluster *i*, thanks to the established technology and the cumulated output is experiencing a larger carrying capacity, K_i, while cluster *j*, which is based on an innovative technology (and a new product with an initially smaller market), is characterised by a smaller one, K_j. Given that firms choose in which cluster to locate on the basis of the level of locational benefits, the only stable equilibrium in the first period is *E'* where $B'_i = B'_j$ and $n'_i >> n'_j$ given that:

- for $n_i > E'$, $B_j > B_i$, therefore firms will leave cluster *i* for cluster *j*, reducing n_i;
- for $n_i < E'$, $B_j < B_i$, thus firms will leave cluster *j* for cluster *i* , increasing n_i.
- In the second period (denoted by ") both functions of locational benefits have shifted up because of the learning economies. However, given the diminishing returns to experience and the carachteristics of the new technology, function B_j rise more than B_i (K_j increase more than K_i). Therefore the new equilibriom becomes *E"* where $B''_i = B''_j$ and $n''_j >> n''_i$

[25] The inequality part of the expression ensure the existence of a non trivial (i.e. when each cluster reaches its own K) interaction between the two clusters.

Figure 5
Learning effects and clusters' leapfrogging



The above results are based on a comparative static framework, where only the relationship between the size of the cluster and the level of locational benefits is explicitely modelled. The following section is devoted to model a similar story within a dynamic framework embedded in the original ecological framework developed in section 2.

5.2. An ecological modelling of clusters' technological life cycle

Let's start by recalling that the development process of the established cluster in isolation is described by an equation similar to (5a):

$$G_i = \dot{n}_i = r_i \, n_i(t)\left(1 - \frac{n_i(t)}{K_i}\right) \tag{9}$$

Let's also assume that, after a certain time[26] from the birth of cluster *i*, an improved new technology is discovered. From section 4.1. it is already known that the technology will not be adopted by cluster *i*, due to the cumulated experience in the old technology which grant it a higher productivity, so another cluster based on the new technology

[26] With τ being the time lag between the birth of cluster *i* and of cluster *j*.

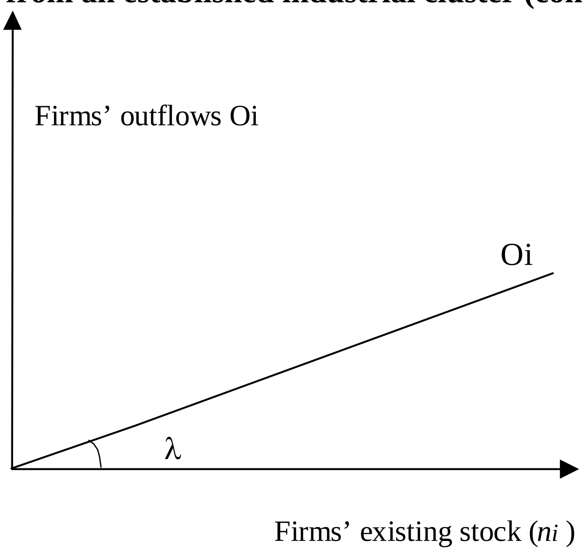
(let' call it cluster *j*) is founded on a previously "deserted" space (where there is no experience of any technology).

Because of the superior performances of the new technology, for a given level of cumulated output, and the larger learning economies, the new cluster will attract a share λ of the firms located in cluster *i*. Therefore cluster *i* will experience an outflow of firms as described by equation (10) and depicted in figure 6:

$$O_i = \dot{m}_i = \lambda\, n_i \tag{10a}$$

Graphically the outflow can be represented in figure 6.

Figure 6
The outflows from an established industrial cluster (constant out-take)



However it seems reasonable to suppose that the outflow from cluster *i* (i.e. the share of its firms' stock) will be also proportional to the industrial mass of cluster *j*. Equation 4a can be modified to take into account this remark by substituting $\Lambda = \frac{\lambda\sqrt{n_i n_j}}{n_i}$ to the original value of the slope of the outflow function (λ), thus modelling $\dot{m}_i$ as a function of the product of the industrial masses of the two clusters[27]. Formally

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[27] Which is the usual way to model the interaction between two populations in the population ecology literature from Lotka (1925), to Maynard Smith (1974), to Roughgarden (1979). For an application to industrial and regional economics see Dendrinos and Mullaly (1985), Nijkamp and Reggiani (1992). For an explicit application to industrial clusters see Maggioni (2002a).

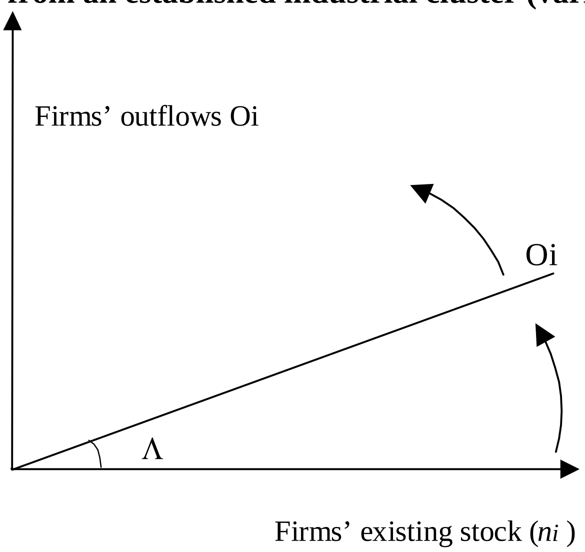
$$O_i = \dot{m}_i = \Lambda n_i = \frac{\lambda\sqrt{n_i\, n_j}}{n_i} n_i = \lambda\sqrt{n_i\, n_j} \tag{10b}$$

The growth of cluster *j*, because of the use of the innovative technology, will follow a cubic logistic function as described in equation (11):

$$G_j = \dot{n}_j = r_j\, n_j^2(t)\left(1 - \frac{n_j(t)}{K_j}\right) \tag{11}$$

Therefore the slope of O_i will grow overtime, being dependent on the (square root of the) product of the industrial mass of cluster *i* and cluster *j*, starting from zero and growing until both clusters reach their ceiling level[28].

Figure 7
The outflows from an established industrial cluster (variable out-take)



The net growth of cluster *i* will depend on the difference between G_i and O_i or more formally:

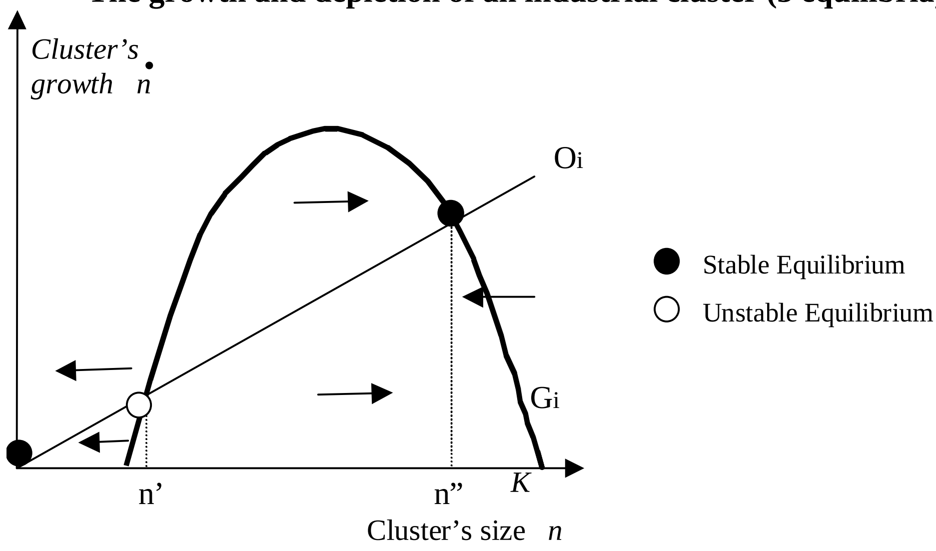
$$N_i = G_i - O_i = \dot{n}_i = r_i\, n_i^2(t)\left(1 - \frac{n_i(t)}{K_i}\right) - \Lambda n_i \tag{12}$$

[28] While the functional form adopted in the simulations is non linear, the qualitative results (i.e. the number and stability of equilibria) can be graphically expressed with a linear approximation without loss of generality.

The value of such an expression cannot be analytically calculated but it is possible to study the characteristics of the results through the following diagrams in a sort of comparative static analysis and then run a series of simulations.

Graphically the solution of equation 6 can be described by overlapping figures 3 and 6 as in figure 8.

Figure 8
The growth and depletion of an industrial cluster (3 equilibria)



At each moment of time the dynamics of the cluster will be determined by the relative position of G_i and O_i. Every time $G_i > O_i$, n_i will increase, every time $O_i > G_i$, n_i will decrease. $\dot{n}_i$ will be equal to zero, thus n_i will be constant over time only at the intercept with the horizontal axis and when $G_i = O_i$. In general, according to the size of cluster *i*, three different dynamics may emerge.

1) If $0 \leq n_i < n'$, the cluster will unravel until it disappears;

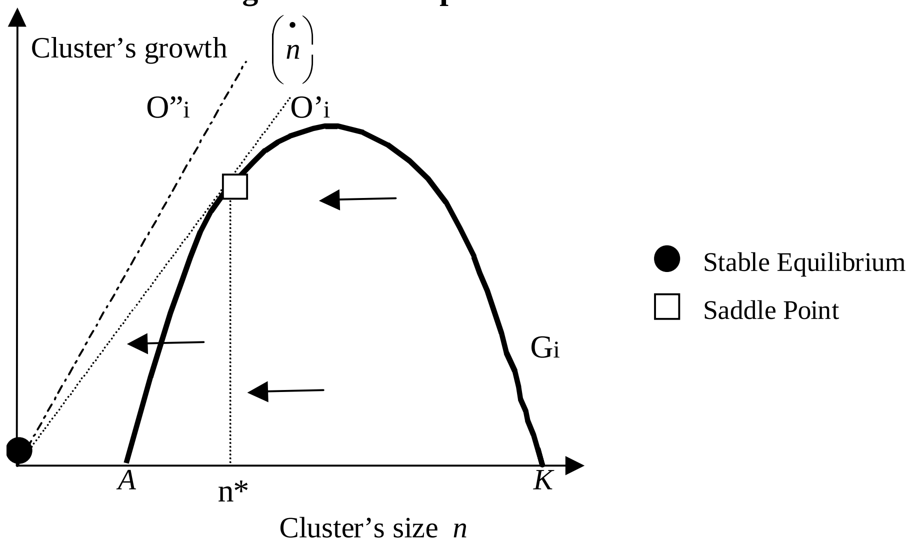
2) if $n' \leq n_i < n''$, the cluster will grow and reach size n" (with n" < K);

3) if $n'' \leq n_i$, the cluster will decrease until size n'' is reached.

0 and n" are stable equilibria, while n' is an unstable one.

When O_i grows, two alternative situations may emerge as depicted in figure 9

Figure 9
The growth and depletion of an industrial cluster



When $O_i = O_i^{'}$, the equation will display two equilibria (a stable one and a saddle point):

1) If $0 \le n_i < n^*$, the cluster will unravel until it disappears;

2) if $n^* > n_i$, the cluster will decrease until size n* is reached.

When $O_i > O_i^{'}$, the equation will display only one stable equilibrium (the origin).

Thus the development path of cluster *i*, given the existence of cluster *j*, will depend on three parameters:

1) r_j : the intrinsic growth rate of cluster *j*;

2) K_j : the carrying capacity of cluster *j*;

3) λ : the share of "migrant" firms in cluster *i*[29];

and on the time lag existing between the start of cluster *i*, and the start of cluster *j*.

A series of simulation show that: the lower the value of each of the three parameters (keeping constant the other two), and the longer the time lag, the more likely cluster *i* will "survive" the competition of cluster *j*; conversely the higher the value of each of the

[29] Λ_i will take into account these three effects together, that's why it is better to look singularly at r_i, K_i and $\lambda_i$in order to disentangle each single effect.

three parameters (keeping constant the other two), and the shorter the time lag, the more likely cluster *i* will be "destroyed" by the existence of cluster *j*.

6. Policy implications

Local policy makers a/o private agents interested in the development of cluster *i* (as the "developers" in Henderson, 1977) have two different policy alternatives, which correspond to the above mentioned parameters *r* and *K*.

By referring to equation (9) it is possible to distinguish between two main types of policy interventions alternatively aimed at:

i) increasing the maximum rate of cluster's growth (by increasing r_i),

ii) raising the long run equilibrium size of the cluster (by increasing K_i).

Let us now consider in details these two types of policy interventions.

An *r*-type policy is designed to increase the positive externalities which are endogenously generated by the location of a new firm in the cluster. The intrinsic rate of growth, r_i, expresses the largest possible "attraction and generation" power[30] of a given number of located firms and influences the growth rate of the cluster. An *r*-type policy explicitly supports the role played by agglomeration economies and knowledge spillovers in the development process of a cluster. The parameter r_i also expresses the difference between firms' birth and mortality rates in the region $\left(r_i = \beta_i - \delta_i\right)$. An *r*-type policy can therefore aim at increasing the birth rate, and/or at decreasing the firms' "infant mortality" rate, within the region through appropriate interventions (such as innovation diffusion supporting policies, start-up incentives, provision of business planning services, diffusion of venture capital activities, etc.). An *r*-type policy is therefore a policy intervention to be used in order to foster the initial phase of development of a cluster in an initial "hostile" environment. It must be implemented when the targeted area is in the initial stages of development, either in a particular industry or more generally in any industry.

[30] Which encompasses the entry of firms that were located outside the cluster and the "birth" of new firms inside the cluster.

A *K*-type policy is designed to increase the regional "carrying capacity" which is the region's ability to sustain a given number of profitable "representative"[31] firms. Since the carrying capacity is a function of the local endowment of resources (inputs and infrastructures) and of the average level of use of these resources made by resident firms, then any public policy aimed at increasing the quantity and/or quality of local inputs and infrastructures, and at raising the efficiency of local firms can be defined as a *K*-type policy.

Although it may well be the case that between *r*-type, *K*-type policies there exist some sort of intrinsic incompatibility; any policy maker faces a more simple and obvious trade off between these two policies given by the limited budget he/she can use to foster the process of local industrial development. Budget constraint means therefore that the policy maker must use some ordering criterion to make the best choice.

In general, it has been observed (Maggioni, 2002b) that the desirability of these different development policies is crucially dependent on the preferred target of the intervention, the chosen time framework for the implementation of the policy, the level of development of the targeted cluster and the state and variability of the relevant external macro-economic conditions.

As far as the target of the policy is concerned, *r*-type policies are mainly addressed to firms, while *K*-type policies usually target the economic environment and the productive and urban infrastructures of the local economic system. According to this taxonomy r-type policies imply interventions such as start-up incentives, fiscal allowances, information diffusion programmes. The fostering of the local university and the strengthening of the regional network of transport and communication infrastructures can be defined as *K*-type policies.

An alternative criterion, relates to the time horizon which is needed for the implementation of the economic policy interventions. Usually *r*-type policies generate results in the short run, while *K*-type policy needs a longer time period to be effective. On the other hand, while the first type merely influence the starting date and speed of development (without changing any structural conditions), *K*-type policies are the only

[31] The concept of representative or average firms is used in this paper to take into account the fact that, in reality, firms differ in size and that the growth of an high-tech cluster may imply either the increase in the number of established firms (i.e. the entry of new firms in the region) or the growth in size of a number of located firms. For a formal framework which explicitly models in different ways the entry and the growth of firms, see Swann et al. (1998).

ones capable of moving the cluster size from a lower equilibrium level to an higher one, thus ensuring higher sustainable long-run growth.

A third criterion refers to the stage of development of the targeted region. A *r*-type intervention is perfectly suited to be implemented in a "developing" region where the main problem is the establishment and early survival of the "seed" firms within the cluster. Finally a *K*-type intervention is designed to be implemented in an industrially developed area where competition on inputs and congestion of infrastructures are the main obstacles to the further development of the cluster.

A final criterion is associated with the state and variability (i.e. depth and frequency of exogenous shocks) of the relevant[32] external macro economic environment. According to macro-economic conditions the best development strategy may involve pure *r*-type, or pure *K*-type policies when the environment is stable; an intermediate policy when shocks are frequent and limited; and a mixed policy (i.e. a weighted combination of pure *r*-type and pure *K*-type) when shocks are deep but infrequent[33].

More specifically the different policy interventions have been compared on the basis of a twofold experiment: in the first part it has been assumed that each euro spent by the policy maker has a similar effect on the three different policies (in terms of overcoming the critical mass, increasing the intrinsic growth rate, raising the carrying capacity of the cluster); in the second part it has been assumed that it is comparatively easier to lower the general entry and relocation costs (*r*-type policy), than to overcome the structural constraints hindering the cluster's growth (*K*-type policy).

A series of simulations, whose results are described in the appendix, show that, *r*-type outperform (in terms of effectiveness) *K*-type policies when the only threat for the established cluster is the development of the new one[34]. This result is further reinforced if one considers that *r*-type are also more efficient than *K*-type policies.

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[32] For an open and internationally integrated region the relevant external environment may well be the world, for a closed and underdeveloped region the relevant environment is likely to be limited to the nation, for an intermediate type of region, the external macro-environment is a group of countries (i.e. Europe for a European country).

[33] For a detailed analysis of the relevance of the external macro-economic conditions, see Gambarotto-Maggioni (1996).

[34] The effectiveness of the different policies has been tested against three different sensibility tests performed on r_j, K_j, and λ.

7. Conclusion

The spatial agglomeration of a number of innovative firms, which causes the genesis of a new high-tech cluster is such a complex and serendipitous phenomenon that no theoretical approach neither econometric estimation may pretend to fully explained it.

This paper has followed a different strategy, by adopting the population ecology approach, and has focussed on the interactions existing between technological innovation and the life-cycle of clusters.

Thus, in a sense, the paper confirmed the claim that industrial location patterns are created through “the process of growth rather than through a process of efficient allocation of plants across a static economic landscape” (Storper and Walker, 1989, p. 70) and that “industries produce regions (clusters) and are capable of creating their own geography”.

This paper points out the importance of “lateral thinking” in development planning: both scholars and policy makers should in fact always look carefully at the industrial and technological dynamics which may swiftly transform a “new” cluster into an “old” one and reverse the direction of the cumulative causation process thus transforming a successful developing cluster into a decaying one.

Appendix

The simulations used in the paper has been conducted on the basis of the following benchmark case.

$K_i = 100$, $K_j = 120$, $r_i = 0.1$, $r_j = 0.2$, $n_i(0) = 1$, $n_j(0) = 1$, $\tau = 20$, $\Lambda = 0.05$, $\Delta t = \frac{1}{5}$[35].

In order to perform the simulation it has been necessary to transform equation (12) into an equivalent difference equation version as follows

$$N_i = G_i - O_i = \Delta n = r_i \, n_i^2(t)\left(1 - \frac{n_i(t)}{K_i}\right) - \Lambda n_i \tag{12b}$$

The first set of simulations have been conducted by performing sensibility tests on the following parameters (K_j, r_j, Λ, τ) raising their value and keeping constant the value of the others until cluster *i* was driven to extinction.

The policy experiment has been conducted in the following way.

- It has been exogenously assumed that an *r*-type policy would double the intrinsic growth rate of cluster *i* ($r_i^P = 2r_i = 0.4$); while a *K*-type policy would double the carrying capacity of cluster *i* ($K_i^P = 2K_i = 200$)[36]
- It has been chosen a value of the interaction coefficient ($\Lambda = 0.7$) which the first set of simulations have shown to produce the extinction of cluster *i*.

  $K_i = 100$, $K_j = 120$, $r_i = 0.1$, $r_j = 0.2$, $n_i(0) = 1$, $n_j(0) = 1$, $\tau = 20$
- Each type of policy has been performed on cluster *i* to check whether it was able to sustain the growth of cluster *i* even in presence of an "attractive" cluster *i*.

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[35] The simulation package (Stella Research 7.02) transforms the original differential equations of the theoretical model into difference equations. Therefore the choice of Δt (the interval of time between calculations) is somehow crucial in order to avoid "weird" results (it must be remembered that a logistic equation in discrete time may even produce chaotic behaviours). It should also be noted that throughout the simulations "time" must be intended as "logical time" (i.e. runs) and not as "historic time".

[36] Different experiments have been performed by attributing different values to different policy interventions. In particular, table 1 shows results also for an r-type policy which raises the intrinsic growth rate by one and a half.

- A sensibility tests has been performed on the following parameters (K_j, r_j, Λ) raising the value of each parameter and keeping constant the value of the others until cluster *i* was driven to extinction. The larger the value, the better the policy.

The following table shows the highest value of K_j, r_j, Λ, still compatible with the existence of cluster *i* and n_i* (i.e. the largest possible size of cluster *i* in that given environment).

	Sensibility on r_j		**Sensibility on K_j**		**Sensibility on Λ**	
Policy interventions	r_j	n_i*	K_j	n_i*	Λ	n_i*
$K_i^P = 2K_i = 200$	0.35	130	208	67	0.10	93
$r_i^P = 2r_i = 0.4$	1.50	39	331	35	0.14	44
$r_i^P = 1.5r_i = 0.3$	0.39	52	224	35	0.11	39

References

Anton J.J. – Yao D.A. (1995), Start-ups, spin-offs, and internal projects, *Journal of Law, Economics and Organizations*, 11, pp. 362-378.

Arthur W.B. (1988), “Urban System and Historical Path Dependency”, in Ausubel J.H. and Herman R. (eds.), *Cities and Their Vital Systems*, National Academy Press, Washington D.C., pp. 85-97.

Arthur W.B. (1990), Silicon Valley Locational Clusters: When Do Increasing Returns Imply Monopoly?, *Mathematical Social Sciences*, 19, pp. 235-251.

Banerjee A.V. (1992), A Simple Model of Herd Behavior, *The Quarterly Journal of Economics*, 107 (3), pp. 797-817.

Bass F. (1969), A New Product Growth Model for Consumer Durables, *Management Science*, 15, pp. 215-227.

Bikhchandani S. - Hirshleifer D. - Welch I. (1992), A Theory of Fads, Fashion, Custom and Cultural Change as Informational Cascades, *Journal of Political Economy*, 5, pp. 992-1026.

Belussi F. (ed) Nuovi modelli di impresa, gerarchie organizzative ed imprese rete, FrancoAngeli, Milano.

Bramanti A – Maggioni M.A. (1997) (eds.), *La dinamica dei sistemi produttivi territoriali: teorie, tecniche, politiche*, Angeli, Milano.

Brezis E.S. - Krugman P. (1997), Technology and the Life Cycle of Cities, Journal of Economic Geography, vol. 2, n. 4, pp. 369-383

Brezis E.S. - Krugman P. - Tsiddon (1993), Leapfrogging in International Competition: A Theory of Cycles in National Technological Leadership, *American Economic Review*, vol. 83, n.5, pp. 1211-1219.

Carrol G.C. (1988) (eds.), *Ecological Models of Organizations*, Ballinger, Cambridge (Mass.)

Choi J.P. (1997), Herd Behaviour, the “Penguin Effect”, and the Suppression of Informational Diffusion: an Analysis of Informational Externalities and Payoff Interdependency”, *Rand Journal of Economics*, vol.28, n. 3, pp. 407-425.

Dahl M.S. - Pedersen C.O.R. - Dalum B. (2003), Entry by spinoff in a high-tech cluster, DRUID W.P. n. 11-3.

David P.A. (1969), A Contribution to the Theory of Diffusion, *Centre for Research in Economic Growth Research Memorandum*, 71, Stanford University, Stanford.

David P.A. - Rosenbloom J.L. (1990), Marshallian Factor, Market Externalities and the Dynamics of Industrial Localisation, *Journal of Urban Economics*, 28, pp. 349-370.

Dendrinos D.S.- Mullally H. (1985), *Urban Evolution. Studies in the Mathematical Ecology of Cities*, Oxford University Press, Oxford.

Farrell J. - Saloner G. (1985),"Standardization, Compatibility, and Innovation, *Rand Journal of Economics*, vol.16, n. 1, pp. 407-425.. 701-83.

Farrell J. - Saloner G. (1987), "Competition, compatibility and Standards: The Economics of Horses, Penguins, and Lemmings", in Gabel H.L., *Product Standardization and Competitive Strategy*, Elsevier, Amsterdam, pp. 1-21

Feldman M.P.(2003), *The Locational Dynamics of the U.S. Biotech Industry: Knowledge Externalities and The Anchor Hypothesis*, mimeo.

Feldman M.P. - Francis J.L.(2003), *Home grown solutions: Fostering Business Formation Through Science and Technology Policy*, mimeo.

Folloni G. - Maggioni M.A. (1994), Un modello dinamico di crescita regionale: leader e attività indotte, *Quaderni della ricerca di base "Modelli di sviluppo e* regional competition*"*, 3, Università Bocconi, Milano.

Gambarotto F. - Maggioni M.A. (1998), Regional Development Strategies in Changing Environments: an Ecological Approach, *Regional Studies*, n. 32, pp. 49-61

Garofoli G. (1991), *Modelli locali di sviluppo*, FrancoAngeli, Milano.

Grilliches Z. (1957), Hybrid Corn: an Exploration in the Economics of Technological Change, *Econometrica*, 25 (4), pp. 501-522.

Hannan M.T. - Carrol G. (1992), *Dynamics of Organizational Populations: Density, Legitimation, and Competition*, Oxford University Press, Oxford.

Hannan M.T. - Freeman J. (1989), *Organizational Ecology*, Harvard University Press, Cambridge (Mass.).

Hanson G. H. (1996), Agglomeration, Dispersion and the Pioneer Firm, *Journal of Urban Economics*, 39, pp. 255-281.

Henderson J.V. (1977), *Economic Theory and the Cities*, National Academic Press, New York.

Hirshleifer D. (1993), The Blind Leading the Blind: Social Influences, Fads, and Informational Cascades, *Working Paper of the Anderson Graduate School of Mana*gement, #24, UCLA, Los Angeles.

Klepper S. – Sleeper S. (2002) Entry by spinoffs, Mimeo, Carnegie Mellon University, Pitsbourg,

Ireland N. and Stoneman P. (1985) ‘Order Effects, Perfect Foresight and Intertemporal Price Discrimination’ *Recherché Economique de Louvain* , 51, 1, pp. 7-20

Ireland N. - Stoneman P. (1986), Technological Diffusion, Expectations and Welfare, *Oxford Economic Papers*, 38, pp. 283-304.

Isard W. (1951), Distance Inputs and the Space Economy: the Locational Equilibrium of the Firm, *Quarterly Journal of Economics*, 65, pp. 373-397.

Isard W. (1956), *Location and Space-economy*, MIT Press, Cambridge (Mass.).Jacobs J. (1969), *The Economy of Cities*, Random House, New York.

Lotka A. J. (1925), *Elements of Physical Biology*, Williams & Wilkins, Baltimore.

Maggioni M.A. (1993), *Ecological Dynamics and Critical Mass Processes in the Location of High Tech Firms*, paper presented at the 40th RSAI (Regional Sciences Association International) Conference, North American Section, Houston, 11-14 November.

Maggioni M.A. (2000), *Structure and Dynamics of High-Tech Clusters: an Econometric Exercise*, Quaderno n. 12, 2000 del Dipartimento di Economia, Istituzioni e Territorio, Università degli Studi di Ferrara, Ferrara, Luglio 2000.

Maggioni M.A. (2002a) *Clustering Dynamics and the Location of High-Tech Firms*, Springer Verlag, Heidelberg and New York

Maggioni M.A. (2002b) “The Development of High-Tech Clusters: Theoretical Insights and Policy Implications” in Feldman M, Massard N., (eds.) *Institutions and Systems in the Geography of Innovation*, Kluwer, Dordrecht, pp. 309-340.

Maggioni M.A. (2004a) High-tech Firms’Location and The Development of Innovative Industrial Cluster: A survey of the Literature, *Economia Politica*, n.1, a. XXI, n.1,.pp.127-165.

Maggioni M.A. (2004b) “Of Flies and Elephants: Some Observations on Enterprise Policy Design and Implementation”, in Baussola M., Timpano F., *Economic development and local policies*, Giuffrè, Milano (forthcoming).

Maynard Smith J. (1974), *Models in Ecology*, Cambridge University Press, Cambridge.

Markusen A. Sticky Places in Slippery Space. A Typology of Industrial Districts, *Economic Geography*, n.72, pp. 293-313.

Marshall A. (1920), *Principles of Economics*, McMillan, London.

Marshall A . (1921), *Industry and Trade*, McMillan, London.

Nijkamp P. - Reggiani A. (1992), *Interaction, Evolution and Chaos in Space*, Springer-Verlag, Heidelberg and New York.

Nocke (2003), "A Gap for Me: Entrepreneurs and Entry", Penn Institute for Economic Research, WP, n. 03-019, Philadelphia, (mimeo).

Paniccia I. (1998), One, a Hundred, Thousand of Industrial Districts. Organizational Variety in Local Network of Small and Medium-sized Enterprises, *Organization Studies*, vol 19, n. 4, pp. 667-699

Papageorgiou Y.Y. (1979), Agglomerations, *Regional Science and Urban Economics*, 9, pp. 41-49.

Pascal A.H. - McCall J.J. (1980), Agglomeration Economies, Search Costs and Industrial Location, *Journal of Urban Economics*, 8, pp. 383-388.

Pearl R. - Reed L.J. (1925), Skew-Growth Curves, *Proceeding of the National Academy of Natural Sciences of the USA*, 11, pp. 16-22.

Quirmbach H.C. (1986), The Diffusion of New Technology and The Market for an Innovation, *Rand Journal of Economics*, 17, pp. 33-47.

Rauch J.E. (1993) Does History Matter only when it matters little? The case of City-Industry Location, *Quarterly Journal of Economics*, 108, p. 843-867.

Roughgarden J. (1979), *Theory of Population Genetics and Evolutionary Ecology: an Introduction,* MacMillan, New York-London.

Richardson H. W. (1978), *Regional and Urban Economics*, Penguin Books, Harmondsworth.

Rocco L. (2003), *Externalities in the Economics of Science*, mimeo, University of Milan Bicocca, Milan.

Reinganum J.F. (1981), On the Diffusion of New Technology: A Game Theoretic Approach, *Review of Economic Studies*, XLVIII, pp. 395-405.

Staber U. (1997), An Ecological Perspective on Entrepreneurship in Industrial Districts, *Entrepreneurship and Regional Development*, 9, pp. 45-64.

Storper M. - Walker R. (1984), "The Spatial Division of Labour: Labour and the Location of Industries", in Sawers L. - Tabb W.K. (eds.), *Sunbelt/Snowbelt: Urban Development and Regional Restructuring*, Oxford University Press, Oxford, pp. 19-47.

Swann G.M.P. (1993), Can High Technology Services Prosper if High Technology Manufacturing Doesn't, *Centre for Business Strategy Working Paper Series*, 143, London Business School, London.

Swann G.M.P. - Prevezer M. – Stout D. (1998) (eds.), *The Dynamics of Industrial Clustering*, Oxford University Press, Oxford.

Staber U. (1997), An Ecological Perspective on Entrepreneurship in Industrial Districts, *Entrepreneurship & Regional Development*, n. 9, pp. 45-64.

Tauchen H., Witte A.D. (1983), An Equilibrium Model of Office Location and Contact Patterns, *Environment and Planning A*, 15, pp. 1311-1326.

Miyao T. - Kanemoto Y. (1987), *Urban Dynamics and Urban Externalities*, Harwood Academic Publishers, London.

Thirtle C G. - Ruttan V.W. (1987), *The Role of Demand and Supply in the Generation and Diffusion of Technical Change*, Harwood Academic, Chur.

Verhulst P.F. (1845) Recherches Mathématique sur la loi d'accroissement de la population, *Nouveaux Mémoires de l'Académie Royale des Sciences et Belles-Lettres de Bruxelles*, 18 (2), pp. 3-38.

Vettas N. (1999), Location as a signal of quality, *CEPR WP* n. 2165, Centre for Economic Policy Research, London.

Weber A. (1929), *Theory of the Location of Industry*, Chicago, Chicago University Press.

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