THE NEW APPROACH TO REGIONAL ECONOMICS DYNAMICS - PATH DEPENDENCE AND SPATIAL SELF REINFORCING MECHANISMS

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Abstract

Agglomeration dynamics are stable on the short term and instable on medium-long term. In the so-called "knowledge intense sectors", when a new sector is born, firms are not linked to a specific territory. However, when increasing returns to scale arise, firms begin to look for specialised services and tend to concentrate in a given location. A locational advantage is created and agglomeration economies are concentrated there. Only a technological shock can open opportunity for other territories to attract firms belonging to that sector. A similar dynamic can be assessed also in traditional sectors whose competitiveness depends on their capacity of enhance their linkages with knowledge intense activities. Given the high level of complexity characterising the system, the response to policies cannot be linear and it changes according to the number of linkages agents developed within the system as well as agents' characteristics. In such a condition policy makers have to programme their interventions according to integration context procedure, since the response to the policy and the generalised cause will strongly influence the generalised effect of the policy.

1. Introduction

Globalisation increased the level of competition among regions from all over the world. Although the country effect is still significant, the (competitive) advantage of regions has dramatically changed and, even in some industrialised countries, some areas are suffering for a general worsening of their economic performance (i.e. GDP trends), while some others are enjoying an astonishing development. The ongoing situation confirms part of the theoretical conclusions of the New Economic Geography, and, at the same time, creates a huge number of opportunities for further research on regional development.

For instance, an innovative theoretical approach stretches to draw the economic dynamic as the evolution of complex systems. Complexity can be introduced in economic formalization in many different patterns and shapes. As a first result, a crisis of traditional economic models and (accordingly) of related policies it is often determined. The "Agent Based" models are sophisticated formalisations for studying complexity within regional economy and they represent also the main background for the analysis presented in this section.[3] Specifically, using sophisticated mathematical instruments it is possible to assess ongoing dynamics by combining three main issues. First of all, the presence of multiple specialisations in regions and the effect on consumers' utility function (monopolistic competition à la Dixit – Stiglitz, 1977). Secondly, the effect that territorial contiguity among actors has on local development (shipping charges in transportation costs as in the ice-berg model of Samuelson). Last, the source of better performances in those regions hosting haphazard interactions among firms of different branches and industries (Aoki, 2002 – Storper, Venables, 2003). The first two points are embedded in the New Economic Geography (especially in the Krugman's formalisation), which represents a starting point of modern regional economics. The third point (the evolutionary one) characterizes this contribution, which aims at giving a new interpretation of the concept of endogenous development, here considered as the dynamic development of a complex economic system.

In other words, this paper will assess economic dynamic as a *self-reinforcing mechanism*: a positive (or negative) feedback that characterizes the evolution of a dynamic system. The concept of self-reinforcing mechanism can be expressed as a dynamic system, with path dependence and a positive feedback, which tends to a large variety of asymptotic states. Every evolutionary step of the system influences the next one and then the evolution of the entire system, thus generating *path dependence.* Such a system has a high number of asymptotic states, and the initial state (Time zero), unpredicted shocks, or other kind of fluctuations, can all conduct the system in any of the different domains of the asymptotic states (Arthur, 1988). Furthermore, the system selects the state in which placing itself. Such dynamics are well known in physics, in chemistry as well as in biology and the final asymptotic state it is called the *emergent structure*. The concept of positive feedback in fact is relatively new for the economic science. The latter generally deals with problems of optimal allocation of scarce/insufficient resources, thus the feedback is usually considered to be negative (decreasing utility and decreasing productivity).

Self reinforcing mechanism dynamic can be used to assess many different economic problems with different origins: from those related to the international dimension, to those typical of the

[3] . For other approaches using the agent based formalization, see the contributions of Maggioni M.A. Roncari S.N. and of Bramanti A. Fratesi U. in this publication.

industrial economy, and, last but not least, problems related to regional economics. Many scholars have assessed multiple equilibria and their inefficiency (Marshall 1891, Arrow, Hahn 1971, Brown, Heal 1979, Scarf 1981). Multiple equilibria depend on the existence of increasing returns to scale. If the mechanism of self-reinforcing is not counterbalanced by any opposite force, the output is a local positive feedback. The latter, in turn, amplifies the deviation from some states. Since these states derive from a local positive feedback, they are unstable by definition, so multiple equilibria exist and are efficient. If the *vector field* related to a given dynamic system is regular and its critical points follow some particular rules, then the existence of other critical points or of stable cycles (also called *attractors*) turns out (Marino, 1998).[4] The multi-attractors systems have some particular properties that are very useful for our research (Marino, 1998). Strict path dependence is therefore manifested, and the final state of the system will depend on the particular trail it has been covering during its dynamic evolution from an (instable) equilibrium towards another (instable) equilibrium, and so on. Accordingly, the system's dynamic is a non-ergodic one.

Three are the points where the research can be focussed. First of all, to identify forces that act as attractors for the system; secondly, if these forces exist, assessing the possibility that the system has to move from a lower equilibrium to a higher one (and if so, in which way and how); finally, if this transition from a level to another is spontaneous or need some particular policy (effectiveness of policies). A first remarkable result is that different mathematical instruments obtain the same result. Accordingly, patterns of evolution can be numerous and different from each other, because of the existence of many stable multiple equilibria, and convergence paths (or phase transitions between the states). The stylized facts confirm that the process of regional development is discontinuous and unexpected: as in the case of new territorial agglomeration (clusters) created by a collective reorganization of the local productive framework.

2. Self reinforcing mechanism and complexity in regional economics

For many years regional economics has not been considered in the economic mainstream. Main reasons for such a situation were mainly related to two orders of factors. Firs of all, the perfect competition approach required a world in which all agents were equal (or divided in well-defined categories such as household or firms), without any difference among each other. Secondly, the economic system as a whole was looking for reaching a stable equilibrium and then to maintain it as long as possible. In other words, the steady state was considered as a locus in which the system had not more incentives for moving toward another one. The result of this kind of formalizations was a weak counterfactual, too weak to be benchmarked with the empirical evidence of many regions.

The first attempt to give a theoretical (even if qualitative) basis to the agglomeration dynamics' empirical evidence, dates back to 1890, when Alfred Marshall defined as "external economies" those economies that are external to a single firm but are internal to a specific area which is characterized by an "industrial atmosphere" (the latter being a sort of public good). According to his definition, there are three main pillars that underpin the individual location choice of firms and workers:

[4] For instance, this issue justify the efficiency of lower technology pattern of production within the market

1. the existence of a pooled labour market that enhances the probability to find a job for workers, and, on the other hand, make lower the probability of labour shortage for firms;
2. the localized production of non-tradable specialized inputs;
3. the possibility for firms to gain a better production function thanks to the existence of informational spillover.

Marshall didn't leave a formalized model of its intuition. He avoided to face a theoretic "Gordian Knot" since, the existence of a source of competitive advantage for firms localized in a specific area was a sort of "shock" for the *orthodox* economic theory: the presence of "unexhausted economies of scale at the level of firms undermine[d] perfect competition" (Krugman, 1998). The aim of preserving the coherence and the elegance of the "perfect competition" formalization leaded many scholars to bypass the problem of competitive advantage of firms utilizing the concept of "central city" in their static models considering the territory in a passive form[5]. This clearly appears, for example, in the Christaller (1933) assumption that larger cities can support a wider range of activities, and in the hexagonal market formalized by Lösch (1940), where some specialized economic activities can be undertaken only at a limited number of site.[6]

Both the models of Christaller and Lösch considered a manufacturing sector, which sells its products to an agricultural sector. Accordingly, this kind of approaches were not able to describe the circular feature of production in which some of the demand for manufacturing commodities comes from manufacturing sector itself (*commodities produced using other commodities*). Empirical evidence shows that the presence of a well developed, strongly localized, manufacturing sector is attractive for other firms of the same sector or production chain[7]. This dynamic can be summarized with the expression "circular causation" utilized by Myrdal (1957) to describe a self-fulfilling process in which a given location starts attracting firms from a certain dimension of its manufacturing sector. The circularity of the process is due to the "backward and forward linkages" (Hirschman, 1958), that link firms each other[8]. Furthermore, the physical proximity to suppliers and seller makes lower transactional costs (Coase, 1937).

[5] Territory, in those pioneer formalizations, was homogeneous and isotropous (i.e. the same in every direction). In other words, the basic concept of land space was that of the endless plants of the central USA.

[6] It is important to note that both the formalisations of Christaller and Losh did not give any explanation to the development of the central city, which existed "by default".

[7] The presence of strong relationship among cluster of firms in a well-defined territory was firstly discovered during the 1920s, as a consortium of economists of Columbia University analysed the collocation of firms and industries in New York. They discovered that standardisation of output played a remarkable role in location decision of agents. Firms with a low level of standardisation operating, for example, in the fashion sector, were located in the centre, strictly related to their suppliers or sellers with a strong use of face-to-face relationship. On the contrary, firm with a high level of standardisation and vertical integration (cooperage is the original example), were localized in the city's ring.

[8] "The economies are external in the sense that the form obtains them from outsiders, and they are economies in the sense that the firm can satisfy its variable or part-time needs in this manner more cheaply than it could satisfy them from within. The outsiders, in turn, can afford to cater to the firm's fractional needs because he also caters to many other firms" Hall (1959). This kind of inter-firm relationship, under some particular conditions (high level of environmental trustiness, strong mesoinstitutions, etc.), can be so strong that firms start to externalize their "Chain Value" forming that some scholars call "Value Constellation".

The next step of theory was to recognise the evolutionary trait of external economies. Vernon (1962), after having analysed the New York productive framework during the 1950s, stressed the "rise and spread of external economies": new sector use to be localised in central areas because they need a high concentration of positive externalities. The standardisation of the production reduces the need of specialised external economy and thus firms leave the expensive urban centre and localise in the ring belt of metropolitan areas.

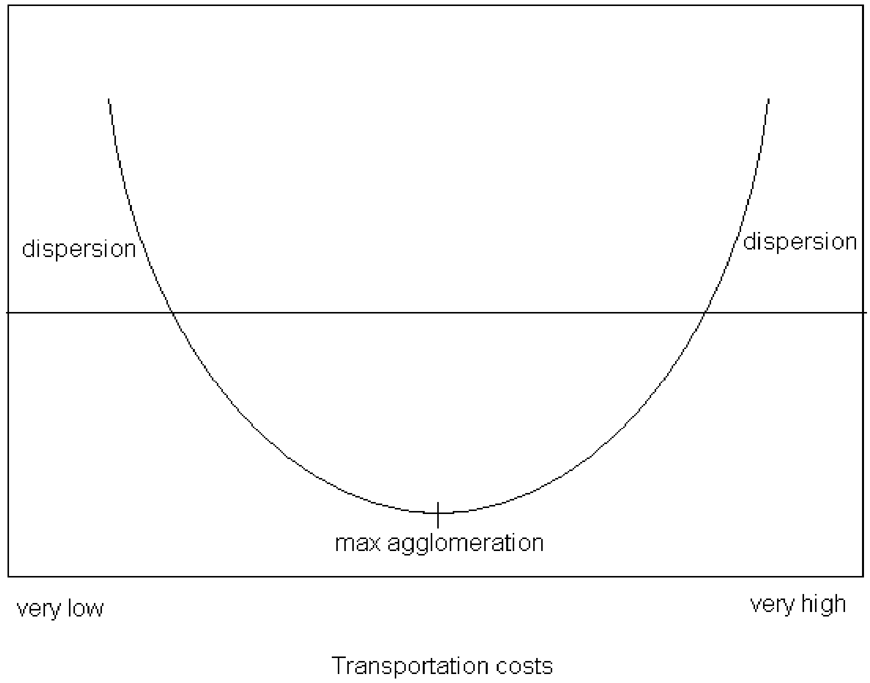
The last issue to specify was to discover the way in which a territory was able to reach the right concentration of (manufacturing) firms to start a self-sustainable process of circular causation. Only in the early 1990s economists found a sound theoretical basis to the empirical evidence by modelling a system of "monopolistic competition" (à la Dixit-Stiglitz) and, so, to consider the "increasing returns of scale" which firms gain by choosing (or for being in) a particular region[9]. Specifically, the three fundamental conditions are:

1. manufacturing sector has to employ a large fraction of the local population in order to generate a large local demand;
2. the sector has to be characterized by the presence of strong economies of scale;
3. low transportation costs.

These condition being satisfied, a region (or an urban area) with a *large local market* and *large availability of goods and services* will attract population from regions whose economic frameworks don't have such as characteristics (or they exist in a less intensive form). In other words, *territories start competing against each other in attracting manufacturing activities*. The approach to agglomeration saw above (New Economic Geography) can be useful to assess some long run dynamics. Indeed, when a broad temporal horizon is considered (i.e. starting from Industrial Revolution) it clearly appears the importance of cheaper transportation costs in the development path of agglomeration. However, "circular causation" seems to reduce dramatically when considering a shorter period (e.g. from the 1970s). Being transportation costs in a constant decreasing trend, empirical evidence seems to suggest a U-shaped relationship between the level of agglomeration and the cost of transportation, as showed in the figure below.

[9] We are referring to the contributions of Fujita, Krugman, and Venables, among others, in the creation of the so called "New Economic Geography"

Fig. 1 - Impact of trasportation costs level on urban agglomeration



The theoretical explanation of this dynamic can be reached by considering a system in which firms produce for both other firms and agricultural sector: when transportation costs are very high firms disperse to meet demand of peasants in every region, on the other hand, if the cost of transportation is very low firms disperse, because of easy access to other firms and consumers. However, this formalisation assumes the intra-city transportation cost to be zero and the inter-city transportation cost to be positive. In other world, it is only useful to understand the conditions in which agglomeration arises in a given large region.

3. Heterogeneity of agents

Regions are often the place of a complex structure of heterogeneous agents acting in different ways. Agents actually are not optimizing a common utility function and they do not share a common endowment of perfect information. Conversely, agents are part of a complex system and every agent (or group of agents) evolves toward unstable equilibria in which they adjust continuously their strategies and their expectation. Strategies and expectations together change the environment itself.

Accordingly, the path toward the equilibrium point (or the linear dynamic of growth, as in the neoclassical Solow formalization) becomes only one of the infinite patterns in which the system may evolve. In this situation even some little changes in some variables are able to bring the system from a pattern to another (an emergent structure). As Arthur has recently stressed (2005) a dynamic like that has three main features:

- *Perpetual novelty* that is the presence of a constant incentive to evolve (while according to static economics agents should have any incentive to move from the achieved equilibrium).

- *Equilibrium indeterminacy* and a selection process that mean the evolutionary path of the system is not given and even small variation can change the intensity or the direction of the vector field.

- *Expectational indeterminacy and inductive behaviour*. In static economic agents are trying to form their expectations about an outcome that is function of their expectations: a self-referential situation. With rational expectation the problem remains, indeed to avoid the insurgency of multiple equilibria, all the agents should adopt the same base theory (based on the same assumptions), which is at least a very special event.

Accordingly, complexity theory can be regarded as an emerging paradigm for understanding the complex dynamics underlying processes in regional economics, as, according to our definition above, regions are complex systems made out of many interacting parts. Complex systems can be described as a graph with nodes (elements) and edges (interactions). The number of interactions that exist between elements can define complexity. Accordingly it is a function of the number of elements (N) acting in the defined domain.

Complexity ranges thus from a maximum level of N elements or agents generating N(N-1) interactions (assuming that interactions are not necessarily mutual) to a minimum of complexity in which there is only one agent (or some group of agents – firms and households) without any direct relationship (or with direct and linear relationships). However, empty graphs cannot really be considered systems because the elements have no relations with other elements.

Agents' interactions can also have a diverse degree of intensity, they can be weak or strong, and usually intensity of interaction is a function of proximity among different agents. In this way it is possible to describe a pattern of interactions between elements along a continuum (instead of using a dichotomy approach). For instance it is possible to use a range in which 0 represent the absence of interactions, and 1 represents a point of the system that is fully connected to the others.

This possibility is particularly useful when a geographical area is taken in account, since geographic proximity is an important generator of mutual interactions. Nonetheless, it is also possible to consider the possibility that some interactions are strong and effective on the long distance.[10] This methodology allows the use of a single parameter for studying complexity. Hence, the latter should not be mistaken for complicated models with many parameters and possible behaviours (Axelrod 1997). There are three main approaches to model complexity that satisfy the conditions assessed above: **Fitness landscapes** or **adaptive landscapes; Complex networks; Percolation.**

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[10] . Storper and Venables (2003) developed a model in which the diffusion of information (intellectual spillovers) depends on the face-to-face interactions of agents. Accordingly, geographical contiguity plays a fundamental role in developing some particular sector in which knowledge evolves quickly. For a deeper assessment of the role of face-to-face interaction in spreading innovation, see Maggioni M.A. Roncari S.N. in this publication.

3.1 Fitness Landscapes Models

In evolutionary biology, **fitness landscapes** or **adaptive landscapes** (Wright, 1932) are used to visualize the relationship between genotypes (or phenotypes) and replicatory success. It is assumed that every genotype has a well defined replication rate (often called *fitness*). This fitness is the "height" of the landscape. Genotypes which are very similar are said to be "close" to each other, while those that are very different are "far" from each other. The two concepts of height and distance are sufficient to form the concept of a "landscape". The set of all possible genotypes, their degree of similarity, and their related fitness values is then called a fitness landscape. A typical formalization is the NK-model. Every component of the system has an "epistatic" relation with the other components or elements.[11] In other word, each agent affects all other elements through a particular property. In the formalization of Kaufman (1993) each element of the system (where N is the total number of elements) is affected by K other elements. Through this model it is possible to simulate the effects of epistasis by constructing a *fitness landscape*. The original model deals with technology, and fitness landscapes are used to refer to efficiency or quality (respectively, for production process, and for products). The fitness value W of a certain strategy s is calculated as the mean of the fitness values w_i of each element i.

$$W(s) = \frac{1}{N} * \sum_{i=1}^{N} w_i(s)$$

This model analyses mutation in the system due to epistatic relations between the elements. If K=0 there are not epistatic relations and w_i has only two random values 0 or 1. When the epistatic relations are at their maximum level ($K=N-1$), any mutation in a single element will produce new fitness values for each element within the system. It is important to note that in the case of clusters of epistatic relations, the system tends to develop a variety of local equilibria at different highness. If the information is moderately complex, the level of equilibrium reached through a local search (within the epistatic cluster) will be quite efficient, and the level of local equilibria (on average) could be quite high. On the contrary, if the information is complex, the local search acted by the cluster could be insufficient to generate a high equilibrium and the local search (or research) will be inefficient.

3.2 Complex networks models

Complex networks are related to the idea of many agents connected in different patterns and with a different intensity. Proprieties of networks are measured by using two fundamental dimensions: the "cliquishness" or *local density of the network*

$$C = \frac{1}{N}\sum_{i} \sum_{j,l \in \Gamma_i} \frac{X(j,l)}{\|\Gamma\|(\|\Gamma\| - 1)/2}$$

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11 . In biology epistatic relations refer to the case in which the action of one gene is modified by one or several genes that assort independently. The two genes may be quite tightly linked, but their effects must reside at different loci in the genome. The gene whose phenotype is expressed is said to be epistatic, while the phenotype altered or suppressed is said to be hypostatic.

(where Γ_i is the set of neighbors of agent I and $\|\Gamma_i\|$ is the size of neighborhood, while X can be either 0 – absent – or 1 – present); and the *average path length between any two agents*:

$$L = \frac{1}{N}\sum_i \sum_{j \neq i} \frac{d(i,j)}{N-1}$$

(where d(i,j) is the shortest path between I and j). According to these two properties, in complex networks is highly probable the formation of cluster among the closer (or less distant) elements.

3.3 Percolation Models

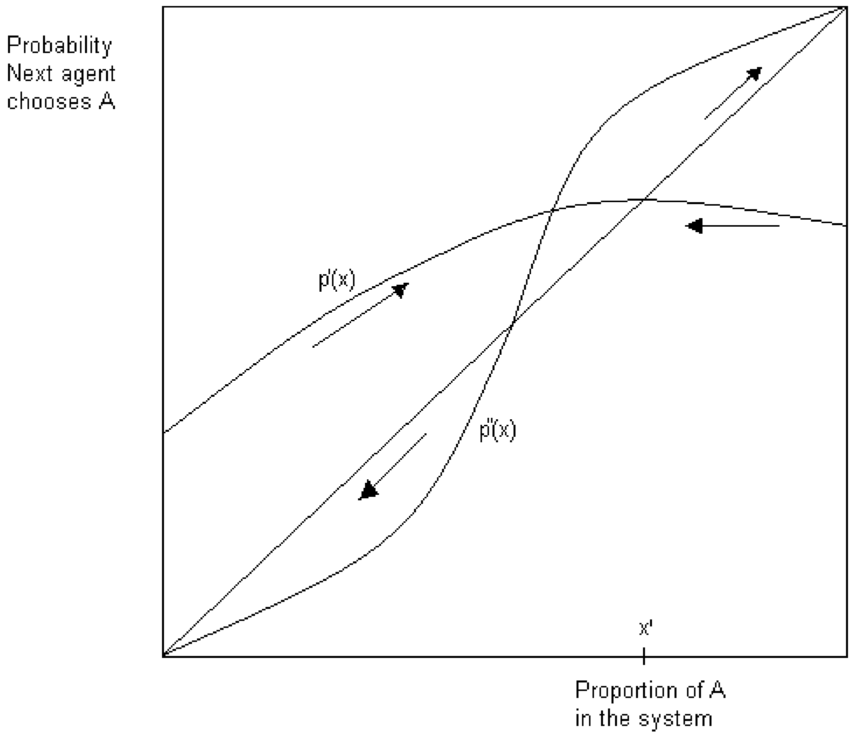
Percolation Models concern the movement and filtering of fluids through porous materials. In others words, they concern a stochastic dynamic of a phenomenon that has the possibility to evolve in an environment that is able, in turn, to influence the dynamic. In economics percolation has been used to model the transmission of information in a given environment. It is mostly based on the concept of phase transition: a change of a given condition in the agent, or in the system, causes a "jump" of the agent that change from one state into another. Broadly arguing, every step of the system's evolution is influenced by the previous one, generating *path dependence.* Such a system has a huge number of asymptotic states, and the initial state (Time zero), unpredicted shocks, or other kind of fluctuations, can conduct the system in any of the different domains of the asymptotic states (Arthur, 1988). Accordingly, the concept of self-reinforcing mechanism can be expressed as a dynamic system, with path dependence and a positive feedback, which tends to a large variety of asymptotic states. Furthermore, the system selects the state in which placing itself. Such dynamics are well known in physics, in chemistry as well as in biology and the final asymptotic state it is called the *emergent structure*. The concept of positive feedback is relatively new for the economic science. Indeed, the economics generally deals with problems of optimal allocation of scarce/insufficient resources, thus the feedback is usually considered to be negative (decreasing utility and decreasing productivity). Path dependence, in turn, is the main characteristic of self reinforcing mechanisms (the other being multiple equilibria in the system, possible inefficiency of the equilibrium, and lock-in).The next section focuses on this approach and shows two different applications of it.

A. Path dependence as an allocation process.

It is not possible to define precisely the dynamic occurring in a system which has the tendency to lock-in in a specific equilibrium, given the existence of multiple equilibria and self reinforcing mechanism. Nonetheless, it is possible to define a system which has some characteristics that allow designing broad classes of analytical system that encompass large number of examples. First of all, to avoid an excessive complexity, the system should follow a linear sequence in which choices are undertaken. Second, the proportion of groups of feasible alternatives influences the choice itself (a concentration of alternatives in a particular group at a particular time influence the choice of the system). Finally, self-reinforcing mechanism usually begins from a "balanced" but unstable position, thus the end-state can be determined from both the initial conditions of the system and from small events outside the model. In this case a little variation in a given exogenous variable causes a catastrophic effect on the entire system. Therefore, the actual state of the system cannot determine the next position of the system, but rather the probability of the next action and then of the next position. Considering a general class of dynamic system, it is possible to assess the dynamic of the allocation process. One of the possible applications of the allocation process concerns, for instance, the distribution of firms in K locations at a certain "event time". The probability that next firm joins category *i* is $p_i(x)$ where *x* is the vector of current proportion or firm location.[12] That formalization allows us to determine, at least implicitly, *p*. By taking into account only two territories (K = 2) is it possible to show in a graphic (Figure 2) all the possible dynamics of the system. In the graph it is possible to observe that if the quantity of agents concentrated in the A region is influenced by the number of agents that are already there. Specifically, if the number of agents in A is larger than a given proportion x^i, the probability that the next agents will decide to localise himself/herself in the region A will be higher. Therefore the region A will attract more agents. On the contrary if the number of agents in A is lower than the proportion x^i, the probability that agents will choice A as their next localisation will decrease overtime. It is worth noting that in this stochastic distribution of elements it is impossible to use the Strong Law of Large Number, since past distributions influence the dynamic of the system, while in the Strong Law increments are independent. In this dynamic process, each choice of the system is irreversible and the process *must* converge to one of the point *p*, of the feasible allocations.

System at t +1 = System at t + the choice with the highest probability + a random exogenous dynamic

Fig. 2 - Two illustrative Allocation functions for dimension K=2 (Arthur, 1988)



[12] "The vector of probabilities $p=(p_1(x), p_2(x),\ldots, p_K(x))$ is the *allocation function* that maps the unit simplex S^K of proportions into the unit simplex of probabilities" (Arthur, 1988)

Without the random exogenous variable the expected value of System at time + 1 will be equal to the actual state at time + 1: ($E(X_{t+1}|X_t) = X_{t+1}$), which is the equivalent deterministic solution. The formalization assessed above is the pillar of many studies concerning the localization of firm by a spin off process[13]. In these models new firms are added by "spinning off" from parent firms one at time. Accordingly, firms are added incrementally to regions with probabilities equal to the proportion of firms in each region at that time. Empirical evidence underpins this process especially in the high tech/knowledge intensive sectors. Every point of the unit simplex (the total of regions) may become an attractor point, so the system can converge to any point. In other words, "chance" dominates completely the dynamic.

B. Path dependence with recontracting processes.

In the allocation process assessed above, choices made by the system are irreversible. But what does it happen if at every time the system can "change its mind" deciding to re-contract previous choices? To model this dynamic it is necessary to consider a Markov-transition in which the concentration of firms in region A influences the location choice of firms in region B that every time can change their location by a "jump" in the other region. The region that attracts more firms increases its probability of attracting the "next one" at time t + 1; hence, self-reinforcing mechanisms are still possible.

To give a formalization let's imagine a case in which there are only two regions K ($K = (A, B) = 2$) and total population is $T = 2N$, with a state variable m. Accordingly, $N + m$ firms will prefer region A, and $N - m$ firms prefer region B. Being $p_{AB}(m)$ the probability that a firm change its location from A to B, and $p_{BA}(m)$ the probability that a firm change its location from B to A (at every unit of time), the probability P(m,t) of finding the system at state m at time t will evolves as:

$$P(m,t+1) = P(m,t)((1 - p_{AB}(m) - p_{BA}(m)) + P(m+1,t)p_{BA}(m+1) + P(m-1,t)p_{AB}(m-1)$$

From which can be derived the Master Equation:

$$\frac{dP(m,t)}{dt} = \left[P(m+1,t)p_{BA}(m+1) - P(m,t)p_{BA}(m)\right] + \left[P(m-1,t)p_{AB}(m-1) - P(m,t)p_{AB}(m)\right] \quad (*)$$

That normalized to the variable x in the continuous interval (-1, 1),

$$x = \frac{m}{N};$$

$$\varepsilon = \frac{1}{N};$$

$$P(x, t) = NP\,(m, t);$$

[13] See Cohen, 1976 or Klepper, 2004.

$$R(x) = \frac{[p_{AB}(m) - p_{BA}(m)]}{N};$$

$$Q(x) = \frac{[p_{AB}(m) + p_{BA}(m)]}{N}$$

Yields the possibility to rewrite (*) in the form of a one-dimensional Fokker-Plank diffusion equation

$$\frac{\partial P(x,t)}{\partial t} = -\frac{\partial}{\partial x} R(x)P(x,t) + \frac{\varepsilon}{2}\frac{\partial^2}{\partial x^2} Q(x)P(x,t)$$

Substituting diffusion functions *R* and *Q* to describe some specific transition mechanism, it is possible to study the evolution of *P* over time and its distribution. It is noteworthy that in recontracting process dynamics transitions remain constant overtime, while in the allocation process formalization transition magnitude was decreasing overtime

To give another example is it possible to show a model that refers to this kind of dynamic in the labour market (Aoki, 2003). By adopting mathematical instruments as the *master equation* (also called Chapman-Kormogorov equation), it is possible to assess a stochastic dynamic in which heterogeneous agents faces same limitations in their mobility or in their possibility to be hired by some sectors of the economy.[14] The presence of a stationary distribution of equilibria instead of a single stable equilibrium is one of the first goals that this kind of formalization gives. Another feature of that approach refers the possibility to consider workers with differences in **work experiences**, **human capital stocks**, **geographical localization,** and off course for the **sector** in which they work. The economy has *K* sectors, and sector *i* employs a certain number n_i, $i = 1, \ldots, K$ of workers. There are two "states" in which a sector could be: the first is the "normal time":

$$y_i = c_i n_i \,.$$

In this situation the sector produces an output that is equal to the demand expressed by the market for the sector's commodities. In the second case the demand is higher than the level of supply, and the sector goes in *overtime* capacity; with the same number of workers produce a higher output than before:

$$y_i = c_i(n_i + 1)\,.$$

Demand for good *i* is given by $s_i Y$, with

$$Y = \sum_{i=1}^{K} y_i$$

[14] The model refers to the entire dynamics in the macroeconomic environment but here we refer to the part of labour market.

and s_i is a positive share of the total output Y referred to goods produced by sector i with $\sum_i s_i = 1$. Every sector has the excess demand defined by:

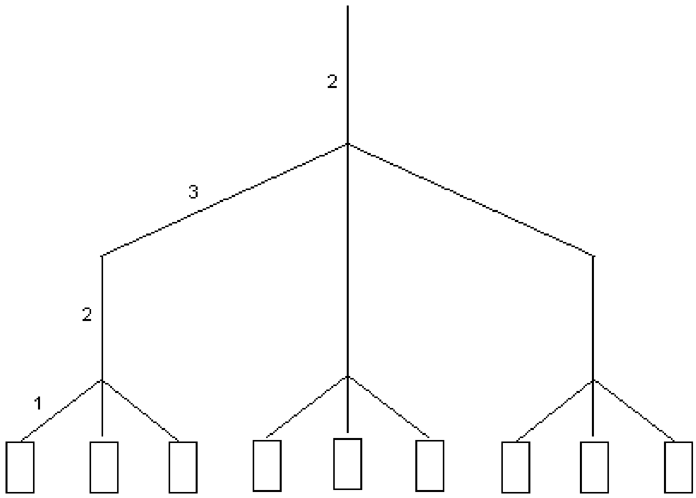
$$f_i = s_i Y - y_i$$

with $i = 1, 2, \ldots, K$.

Sets of sectors with positive and negative excess demand are denoted by

$$I_+ = \{i : f_i \geq 0\} \quad ; \quad I_- = \{i : f_i < 0\} .(**)$$

Changes in Y due to changes in any one of sectors affect the excess demand of all sectors. The model uses (**) as proxy to indicate which group of sectors is profitable (and thus it wants to expand its production), and, conversely, which one is unprofitable (and so it tries to reduce its production). According to the model, only one sector succeeds in adjusting its production up or down by one unit at any given time. The sector with the shortest *sojourn time* will be the one to jumps first (because of path dependence). And so dynamics are only determined by the transition rates in continuous-time Markov chains. Distance among different sectors is defined by using ultrametric distance. Therefore, the economic environment is structured as a tree diagram in which every sector is a "leave" which is connected to the rest of the tree trough "nodes". Transmission of economic shocks in the environment depends on distances among leaves and branches. The distance is measured between "nodes".



Ultrametric distance $d(i, j)$ enjoys the following properties:

a. it is positive unless $i = j$ (in which case it is zero);

b. it is symmetric $d(i, j) = d(j, i)$;

c. it satisfies $d(i, j) \leq max_k \{d(i, k), d(j, k)\}$

Every sector in overtime fills its vacancies (if there were not vacancies the overtime condition creates them) with workers laid off by itself or by the other sectors of the economy. Obviously, workers belonging to the hiring sector have a greater possibility to be hired than workers belonging to more distant sectors. Using the master equation the distribution of the stochastic probability that a certain worker of a certain sector will be hired by a sector can be assessed. Ultrametrics can be introduced also as dummies for institutions and other kind of “special agents” whose actions can influence the system as a whole.[15] Accordingly, the analysis not only can be used to forecast the evolution of the system *sic rebus stantibus*, but also it can show which are the main attractors in the system.

Another important result of this approach is that it may be helpful to design policies taking into account other variables characterising contemporary economy such as natural and environmental resources, human resources, and technology. Furthermore, incorporating these factors in the model does not increase the complexity of the mathematical instrument. This specific issue is broadly analysed in the next section.

15 . The role of institutions in regional agglomeration dynamics is assessed below in section 5.

4. Economic Policies in Spatial Extended Systems: New Paradigms

Description of the evolution of spatialised economies emphasizes the role of new paradigms rather than of classical ones. New factors seem to have replaced the earth, work and physical capital. Natural and environmental resources, human resources and technology are beginning to get the upper hand following the so-called "technological revolution". Co-operation within businesses and between businesses and business systems takes place on a vertical and a horizontal scale in which the local dimension and the territorial variables constitute the catalyst for processes of development. Technological expertise and social capabilities (Latella - Marino, 1996) are the basic elements capable of explaining the different levels of development that can be observed in different territorial contexts. Territorial variables, in other words, are decisive factors in explaining development differentials, especially when associated with the idea of market conceived as a social construction requiring rules that will guarantee its smooth running given that access rights, exchange mechanisms and opportunities for distribution of the wealth generated not only do not reassemble themselves uniformly and autonomously in time and space (Sen, 1984 and 1985), but almost always require outside intervention to achieve the objectives set for development policies. Re-equilibrium policies thus appear necessary to guarantee a more equitable development process. Within the market it is necessary to define collective rules ensuring that positive dynamics (increasing return) can develop through the interaction of the agents operating in it. The territorial dimension and the systemic nature of the production process are elements that are fundamental to the understanding and governing of development processes.

Public intervention in such a scenario cannot simply be thought of as a mechanism for allocating resources within the economy but must assume the role of guide and director of processes taking the shape, on the one hand, of a set of actions aimed at defining and guaranteeing individual access rights and, on the other hand, of interventions aimed at developing the exchange capacities of markets and business systems (Bianchi, 1995). An explanation may be sought in the fact that local communities increasingly interact with the rest of the world in a continuous process of integration and globalization without necessarily responding to stimuli from the central state. This obliges us to re-examine the composition of the economic policy maker's "tool box" and, at the same time, forces us to radically rethink the very meaning of policies government given that the central public authority is no longer able to guarantee the development of the local community in the presence of particular actions enforced by the central authorities (Bianchi, 1995).

Traditional economic policies, when enforced in the context of an open market or of a market characterized by strong interrelations between agents, lose their capacity to produce the expected results because the mechanism of response to the policy maker's input has to deal with a system characterized by high levels of interrelations between individual decisions and which therefore displays collective response characteristics which are different from individual response mechanisms. The consolidated logic of public intervention in economics assumes that the government authority will identify objectives for which the instruments most likely to achieve results which can be verified and therefore simulated are chosen. Traditional macroeconomic policies only work if acting on a closed system for which it is possible to order objectives and priorities with certainty. In this case the policy maker can govern the system of underlying relations by assuming linear type response mechanisms. If these assumptions are not verified, the complexity of the system makes traditional policies pointless, therefore, to govern a complex system policy-makers must equip themselves with a set of objective instruments and programming actions able to cope with non-linearity and the consequences of complexity.

4.1 Planning Actions Spatial Extended Systems: Old and New Approach

From the idea that an economy is a "complex evolving system" in which single individuals are linked to each other by strong relationships, it follows that dynamic characteristics cannot be represented by individual approaches but rather by collective properties subjected to subsequent non-reversible scansions (Arthur, 1988). It is thus conceivable that each economic system, in its evolution, might manifest both a multiplicity of equilibria, each dependent on previous historical interrelations, and the presence of inefficiencies and lock in which can be selected during the evolutionary course of the system to the detriment of possible efficient solutions. Government of an economy thought of as a complex evolving system therefore excludes the possibility that commands might be expressed with a prescriptive type mechanism in mind, as would happen if the system being analysed were essentially closed and characterized by low levels of interactions between agents. To this it must be added the considerable incidence of variables of a territorial nature. Territory cannot be thought of simply as a physical support for business activities but must itself become an active factor conditioning the exploitation of local resources and the capacities of single businesses to cope with international competition. Therefore, the general objective of regional policy becomes that of structural adjustment with a view to greater economic and social territorial integration. So new regional policy must firstly contemplate a "transactive" rather than a "prescriptive" type of approach and the basis for any action must consider not just "what must be done" but "in what manner, by what procedures and with whom". This means making systematic and widespread use at all levels of the principle of subsidiarity which implies that decisions should be taken as near as possible to the problem and be appropriate to its solution, and individual responsibilities should also be identified using the same criterion. Thus the main task of decision-makers in each Spatial Extended System is to aim at reassembling the rules and re-establishing the access rights which are the basis of any subsequent action designed to re-appropriate local culture and raise the threshold of contextual knowledge. On these premises it is possible to imagine the transfer of outside knowledge and the creation of networks which build up the basis for the realization of a self-sustained model of development.

To achieve these aims the *Spatial Extended System* (SES) needs to equip itself with instruments capable of identifying moments of participation and complementarity among all the actors that make up the local system. To do this opportunities must be created to allow the human resources to increase the know-how and acquired cognition that will qualify them to introduce innovative codes and routines within the productive system. If such cognitive improvement occurs, there will be an increase in flexibility and specialization and a greater capacity to understand and govern change and innovation and ultimately an improvement in the overall efficiency of the productive system. The government of a local system which is complex because of the continuous, strong interrelations between the individuals operating within it cannot be of a deterministic kind unless part of it is isolated from the rest of the relations.

The government of a complex system demands a series of deliberations over interventions, which by their intrinsic nature are irreversible, i.e. they produce permanent changes in the state of the system. To return to the now extensively examined concept of SES, multiplicity of equilibria, co-operation, proximity, resilience and freedom of access can be pointed to as some important categories in the description and government of a complex system. The conceptual field within which the local system has to move is, in fact, of a bottom up kind and provides the archetype for programming actions capable of leading the evolutionary paths of the SES towards states of greater growth.

Bianchi's (1995) taxonomy of interventions identifies the following three procedures:

1. programming according to exogenous concepts;

2. programming according to critical situations;

3. programming according to integration contexts.

Programming according to exogenous concepts is nothing more than the traditional concept of programming, achieved by means of the exogenous definition of objectives by the policy maker in conjunction with the identification of the instruments necessary to achieve the pre-established goals. If complexity and environmental turbulence are low, this method of programming is effective. This type of programming enters a crisis when the system enters those critical areas characterized by high levels of turbulence or uncertainty. In such circumstances it is necessary to programme according to critical situations, i.e. to devise programming capable of self-regulation in the presence of criticality and of varying parameters in order to overcome any lock-in or bottle-neck situations. As long as the critical areas are small in size, this approach is sufficient. If, however, levels of turbulence and complexity are so high that criticality can occur at any moment, then it is necessary to programme according to integration contexts, i.e. considering the system as a whole as an organism capable of adapting continuously to the outside environment.

In this case policies have to take into account the changes they induce in the system itself, i.e. the way the system metabolizes them. The need for programming according to integration contexts therefore justifies, as fundamental elements for regional policy, forms of structural adjustment whose objective is to lower the costs of transaction and which concern:

- the social dimension, linked to the quality of life and culture;

- the ecological aspect, closely connected to the urban habitat, the landscape and the ecosystem;
- public institutions and productive sectors, with special reference to the organizational aspect and the quest for efficiency.

Public-private co-operation, improved social standards, the construction of R&S networks and appropriate territorial policies designed to provide the basis for integration are irreplaceable instruments for governing the economy and for leading it to the highest levels of development.

5. An Outline of the Transmission Mechanism of Economic Policy in the Presence of Complexity.

The collective properties of a territorial economic system in relation to the link existing between productivity growth and information could be represented in terms of response function. We would like, at this point, to generalize the previous relationship by constructing an interpretative model which describes the propagation mechanism of economic policy in a situation of complexity. The description of the transmission mechanism logically completes the previous observations regarding objectives and instruments. Single economic policy decisions, aimed at achieving the j-th objective through the use of the i-th instrument, can be represented as an outside stimulus which superimposes itself on interactions between agents.

Agents in this approach are thought of as being spatially distributed and linked to each other by local mutual interactions (of a nearest neighbours type). We use H to indicate the effect of the economic policy. We can thus define an effective Heff stimulus which includes both outside stimulus and agent interaction.[16] Obviously, without agent interaction H and Heff are equal. Heff therefore assumes the form:

$$\mathrm{Heff} = H + \int dr' c(r-r')\delta\gamma(r')$$

Where c(r-r’) is a function of correlation between agents which can constitute an acceptable means of modelling the concept of proximity, $\delta\gamma(r')$ is a variation in the behaviour of agents induced by the policy applied, the integral can be linked to the concept of resilience. This type of behaviour arises in the area of a linear response model for systems with collective properties. The effect of an economic policy on a complex system made up of many agents interacting with each other can therefore be described in this way and modelled, as seen in the previous chapter, by means of the response properties of the system itself. Therefore, in the area of linear response theory we have a cause-effect relationship of the type:

$$E(X) = G(X) \otimes H(X)$$

where E (X) represents the generalized effect, G(X) the response function, and H(X) the generalized cause.

Therefore it is possible to study the generalized transmission mechanism of the economic policy describing the response function as a sort of susceptivity which comes to depend on the distribution of agents within the market. Obviously the type of response depends not only on distribution, but also on the type of interaction between agents.

6 Some conclusive consideration.

The debate in economics between those who maintain that complexity and its causes plays a decisive role in the construction of models with high levels of realism and those who think that a complete and exhaustive description of economic phenomena can be achieved using linear and equilibrium type models regardless of the complexity of the behaviour of agents and markets is

[16] . *Heff* represents the actual output of the implemented policy.

relatively recent. In this work we analysed the relationship between complexity and economic policies from the point of view of regional and territorial economics. The economy as a complex evolving system (Arthur, 1988) therefore implies that:

- individuals are bound to each other by strong relationships;
- dynamic characteristics cannot be represented by means of individual approaches but only by collective properties;
- evolution manifests itself by means of multiple equilibria;
- each equilibrium depends on previous historical interrelations through possible inefficiencies and/or lock-in.

From a conceptual point of view, the main characteristics of the effects that emerge in the dynamic evolution of a system with complex behaviour can be explained by:

- the difficulty prescriptive type regional and territorial policies have in promoting and sustaining economic development;
- the loss of importance of the national dimension: the local dimension clashes with the global dimension;
- the faltering view of economic policy and its propagation mechanism as being based on principles of command and control;
- the inability of a central planner to govern all the underlying relationships between economic agents at any given time according to linear type response procedures.

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