THEORETICAL BACKGROUND

The new approach to regional competitiveness

Introduction

Globalisation increased the level of competition between regions all over the world. Although the country effect is still significant, the (competitive) advantage of regions has dramatically changed and some areas--even in some industrialised countries--are suffering a general worsening of their economic performance (i.e. GDP trends), while some others are enjoying 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.

An innovative theoretical approach extends to drawing the economic dynamic as the evolution of complex systems. Complexity can be introduced in economic formalization in many different shapes and patterns. A crisis of traditional economic models and (accordingly) of related policies is often a first result. The "Agent Based" models are sophisticated formalisations for studying complexity within regional economy and they also will be the main background for the analysis presented in this section. Specifically, by 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 their effect on consumer utility function (monopolistic competition à la Dixit – Stiglitz, 1977). Secondly, the effect that territorial contiguity of actors has on local development (shipping charges in transportation costs as in the ice-berg model of Samuelson). Lastly, the source of higher performance in those regions which host 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 formalisation), which is the starting point of modern regional economics. The third (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.

This part of the essay will assess the economic dynamic as a *self-reinforcing mechanism*: positive (or negative) feedback that characterizes the evolution of a dynamic system. The concept of a self-reinforcing mechanism can be expressed as a dynamic system, with path dependence and positive feedback, which tends to produce a large variety of asymptotic states. Every evolutionary step of the system influences the next and thus the evolution of the entire system, so generating *path dependence*. Such a system has a high number of asymptotic states, and the initial state (Time zero), unforeseen shocks, or other kinds of fluctuations, can lead the system into any of the different domains of the asymptotic states (Arthur, 1988). Furthermore, the system selects the state in which it places itself. Such dynamics are well known in physics, chemistry and biology and the final asymptotic state is called the *emergent structure*. The concept of positive feedback is relatively new in economics. 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).

Sf-reinforcing mechanism dynamics can be used to assess many different economic problems with different origins, from those related to the international dimension to those typical of the 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 self-reinforcing mechanism is not counterbalanced by some opposite force, the output is local positive feedback. The latter, in turn, will amplify 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*) is a result (Marino, 1998).[1] The multi-attractor systems have some particular properties that are very useful to our research (Marino, 1998). Strict path dependence is therefore manifested, and the final state of the system will depend on the particular path it has covered during its dynamic evolution from one (unstable) equilibrium to another (unstable) equilibrium. Accordingly, the system's dynamic is a non-ergodic one.

Three are the points where the research can be focussed. First of all, the identification of forces that act as attractors for the system; secondly, if these forces exist, assessing the possibility that the system will move from a lower to a higher equilibrium (and if so, in which way and how); finally, whether this transition from one level to another is spontaneous or needs some particular policy (effectiveness of policies). A first remarkable result is that different mathematical instruments give 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.

1 For instance, this issue justifies the efficiency of the lower technology pattern of production within the market

Self-reinforcing mechanism and complexity in regional economics

For many years, regional economics has not been considered as the economic mainstream. The main reasons for such a situation are mainly related to two orders of factors. First of all, the perfect competition approach required a world in which all agents were equal (or divided into well-defined categories such as households or firms), without any difference between them. Secondly, the economic system as a whole was trying to reach a stable equilibrium and then to maintain it for as long as possible. In other words, the steady state was considered as a *locus* in which the system had no more incentives to move toward any other state. The result of this kind of formalization was weak and counterfactual, too weak to be benchmarked with the empirical evidence of many regions.

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

1. the existence of a pooled labour market that enhances the probability of finding a job for workers, and, on the other hand, lowers the probability of labour shortages 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 his insight. He avoided facing a theoretical “Gordian Knot” since the existence of a source of competitive advantage for firms localized in a specific area was a sort of “shock” for *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 elegance of the “perfect competition” formalization led many scholars to bypass the problem of the competitive advantage of firms by using the concept of “central city” in their static models considering the territory in a passive form[2]. 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 sites.[3]

2 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 plains of the central USA.

3 It is important to note that neither the formalisation of Christaller or Lösch gave any explanation for the development of the central city, which existed “by default”.

Both the models of Christaller and Lösch considered a manufacturing sector which sells its products to an agricultural sector. Accordingly, this kind of approach was not able to describe the circular feature of production in which some of the demand for manufacturing commodities comes from the 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[4]. This dynamic can be summarised 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" (Chenery, Watanabe, 1958; Rasmussen, 1956; Hirschman, 1958) that link firms to each other[5]. Furthermore, the physical proximity to suppliers and seller makes for lower transactional costs (Coase, 1937; Williamson, 1981).

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

The last issue was to discover the way in which a territory was able to achieve the right concentration of (manufacturing) firms to start a self-sustaining process of circular causation. Only in the early 1990s did economists find a sound theoretical basis for the empirical evidence by modelling a system of "monopolistic competition" (à la Dixit-Stiglitz) and, so, consider the "increasing returns of scale" which firms gain by choosing (or by being in) a particular region[6].

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4 The existence of strong relationships between clusters of firms in a well-defined territory was first 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, closely related to their suppliers or sellers by wide use of face-to-face relationships. On the contrary, firms with a high level of standardisation and vertical integration (cooperage is the original example), were located in the outskirts of the city.

5 "The economies are external in the sense that the firm 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 they also cater to many other firms" Hall (1959). This kind of inter-firm relationship, under some particular conditions (high level of environmental trustiness, strong meso-institutions, etc.), can be so strong that firms start to externalize their "Value Chain", forming what some scholars call a "Value Constellation".

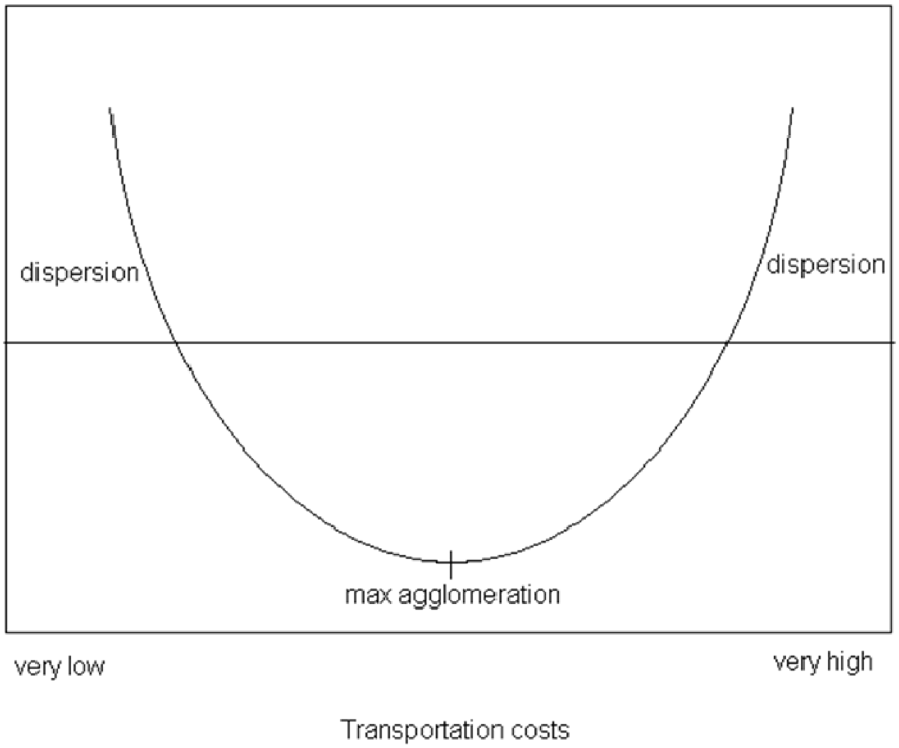
6 We are referring to the contributions of Fujita, Krugman, and Venables, among others, in the creation of the so called "New Economic Geography"

Specifically, the three fundamental conditions are:

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

When these conditions are 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 have then in a less intensive form). In other words, *territories start competing against each other to attract manufacturing activities*. The approach to agglomeration seen 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 the Industrial Revolution) the importance of cheaper transportation costs in the development path of agglomeration is clearly apparent. However, “circular causation” seems to reduce dramatically when a shorter period (e.g. from the 1970s) is considered. Given that transportation costs were 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 shown in the figure below.

Figure 1 - Impact of transportation costs level on agglomeration



This dynamic can be explained theoretically by considering a system in which firms produce both for other firms and for the agricultural sector: when transportation costs are very high firms disperse to meet the demand of farmers 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 words, it is useful only to understand the conditions in which agglomeration arises in a given large region.

Heterogeneity of agents

Regions are often the location of a complex structure of heterogeneous agents acting in different ways. Agents do not actually optimize 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 their strategies and their expectations continuously. Strategies and expectations together change the environment itself.

Accordingly, the path toward the equilibrium point, or the linear dynamic of growth, as in the neo-classical Solow (1970) formalization, is only one of an infinite number of patterns in which the system may evolve. In this situation, even small changes in some variables are able to change the system from one pattern to another (an emergent structure). As Arthur recently stressed (2005) a dynamic like that has three main features:

- *Perpetual novelty*: there is a constant incentive to evolve (while according to static economics, agents should not have any incentive to move from the equilibrium once it is achieved).

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

- *Expectational indeterminacy and inductive behaviour*. In static economics, agents try to form their expectations about an outcome that is a function of their very expectations: a self-referential situation. With rational expectation the problem remains; indeed to avoid the onset of multiple equilibria, all the agents should adopt the same base theory (i.e. 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 up 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 a 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.

Agent interactions can also have differing degrees of intensity, they can be weak or strong, and usually intensity of interaction is a function of proximity to different agents. The presence of a dense network of agents (i.e. firms), in fact, is a necessary but not a sufficient condition for creating dynamic regional competitiveness. According to Schmitz (1998), for instance, this *static* (or *passive*) *dimension of clustering*, characterized by the mere spatial concentration of agents should not be mistaken with a patterns of *active cooperation and interaction* among agents that are constantly cooperating and exchanging information to achieve a *collective efficiency* (Schmitz, 1998).[7] 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 represents the absence of interactions, and 1 represents a point of the system that is fully connected to the others. Nonetheless, it is also possible that some interactions are strong and effective over a long distance.[8] 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 multiple behaviour patterns (Axelrod 1997). There are three main approaches to model complexity that satisfy the conditions imposed above: **Fitness landscapes** or A**daptive landscapes, Complex networks, and Percolation.**

Fitness Landscape Models

In evolutionary biology, **fitness landscapes** or **adaptive landscapes** (Wright, 1932) are used to visualize the relationship between genotypes (or phenotypes) and replicatory

7 . There are several indicators that could be used to measure the passive/static and active dimensions of clustering. Most of national and decentralized statistics allow the elaboration of some measure of spatial concentration in terms of employment, production/value added or the number of establishments. The active dimensions are more difficult to capture through quantitative measures alone, and require additional qualitative assessments of such variables as the pattern of relationships among firms (through technical collaboration and assistance within production and value chains, membership of business associations, informal mechanism of collaboration among business, relationships between businesses), the relation between firms and local governments and universities, among others. Schmitz (1998) and Nadvi and Schmitz (1994) elaborated specific surveys in the context of developing countries in order to detect the degree of collaborative networks within city-regions.

8 Storper and Venables (2003) developed a model in which the diffusion of information (intellectual spillovers) depends on face-to-face interactions of agents. Accordingly, geographical contiguity plays a fundamental role in developing some particular sectors 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.

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" relationship with the other components or elements.[9] 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 (for production process, and for products respectively). 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 relationships between the elements. If $K=0$ there are no epistatic relationship and w_i has only two random values 0 or 1. When the epistatic relationships 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 relationships, the system tends to develop a variety of local equilibria at different heights. 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 carried out by the cluster could be insufficient to generate a high equilibrium and the local search (or research) will be inefficient.

Complex network models

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

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

9 In biology epistatic relationships refer to the case in which the action of one gene is modified by one or several genes that are classed 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 neighbours of agent I and $\|\Gamma_i\|$ is the size of neighbourhood, while X can be either 0 absent – or 1 – present); and *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, the formation of a cluster of the closer (or less distant) elements is highly probable in complex networks.

Percolation Models

Percolation Models refer to the movement and filtering of fluids through porous materials. In others words, they concern a stochastic dynamic of a phenomenon that can 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 the agent to “jump” from one state into another. Broadly speaking, every step in the evolution of the system 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), unforeseen shocks, or other kinds of fluctuations, can conduct the system in any of the different domains of the asymptotic states (Arthur, 1988). Accordingly, the concept of a self-reinforcing mechanism can be expressed as a dynamic system, with path dependence and positive feedback, which tends to lead to a large variety of asymptotic states. Furthermore, the system selects the state in which it places itself. Such dynamics are well known in physics, chemistry and biology and the final asymptotic state it is called the *emergent structure*. The concept of positive feedback is relatively new in economics. Indeed, economics generally deals with problems of optimal allocation of scarce/insufficient resources, thus feedback is usually considered to be negative (decreasing utility and decreasing productivity). Path dependence, in turn, is the main characteristic of sf-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.

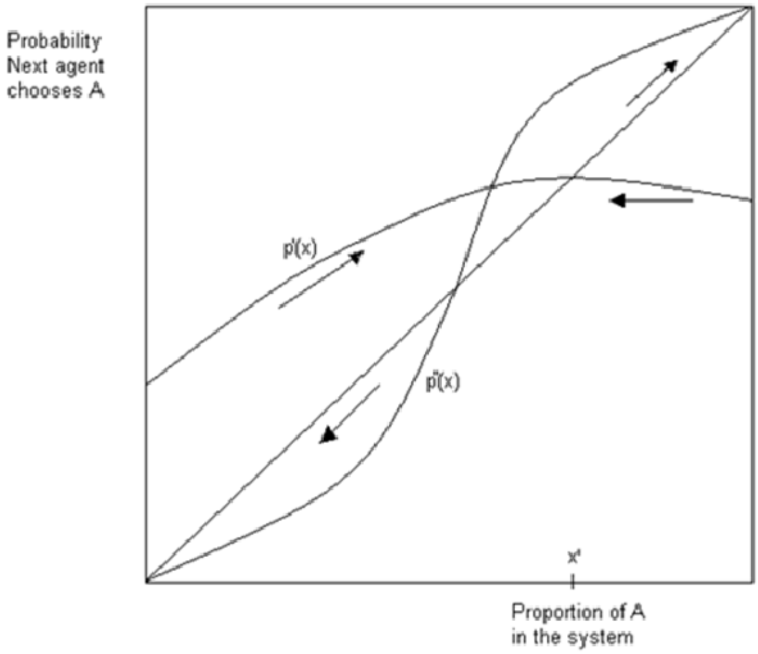
A. Path dependence as an allocation process.

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 a sf-reinforcing mechanism. Nonetheless, it is possible to define a system which has some characteristics that allow broad classes of analytical systems to be designed that encompass large number of examples. First of all, to avoid excessive complexity, the system should follow the 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, a self-reinforcing mechanism usually begins from a "balanced" but unstable position, thus the end-state can be determined by both the initial conditions of the system and by small events outside the model. In this case, a small variation in a given exogenous variable could cause 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 systems, 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 the next firm will join category *i* is $p_i(x)$ where *x* is the vector of current proportion or firm location.[10] That formalization allows us to determine *p*, at least implicitly. By taking only two territories (K = 2) into account, it is possible to show (Figure 2) all the possible dynamics of the system graphically. In the graph, it can be seen 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 agent will decide to locate in 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 choose A as their next location will decrease over time. It is worth noting that it is impossible to use the *Strong Law of Large Numbers* in this stochastic distribution of elements, 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 points *p* of the feasible allocations.

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

10 "The vector of probabilities *p = (p1(x), p2(x),…, pK(x))* is the allocation function that maps the unit simplex *SK* of proportions into the unit simplex of probabilities" (Arthur, 1988)

Figure 2 - Two illustrative allocation functions for dimension K = 2



Source : 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 on the location of firms by a spin off process.[11] 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 the dynamic completely.

B. Path dependence with recontracting processes.

In the allocation process assessed above, choices made by the system are irreversible. But what happens if every time the system can "change its mind", it decides 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 which can change their location every time by "jumping" into the

11 See Cohen, 1976 or Klepper, 2004.

other region. The region that attracts more firms increases its probability of attracting the “next one” at time t + 1; hence, a self-reinforcing mechanism is 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*. Since $p_{AB}(m)$ *is* the probability that a firm will change its location from *A* to *B*, and $p_{BA}(m)$ the probability that a firm will 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 we derive the Master Equation:

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

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

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

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

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

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

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

yields the possibility of rewriting (*) in the form of a one-dimensional Fokker-Plank diffusion equation

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

By 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 worth noting that in recontracting process dynamics, transitions remain constant over time, while transition magnitude decrease over time in the allocation process formalization

To give another example, we can show a model that refers to this kind of dynamic in the labour market (Aoki, 2003). By adopting the mathematical instrument of the *master equation* (also called Chapman-Kormogorov equation), it is possible to assess a stochastic dynamic in which heterogeneous agents face the same limitations in their mobility or in their possibility of being hired by some sectors of the economy.[12] One of the first results that this kind of formalization gives is a stationary distribution of equilibria instead of a single stable equilibrium. Another feature of this approach is the possibility of considering workers with differences in **work experience**, **human capital stock**, **geographical location,** and 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 into *overtime* capacity; with the same number of workers producing a higher output than before:

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

Demand for goods i is given by $s_i Y$, with

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

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

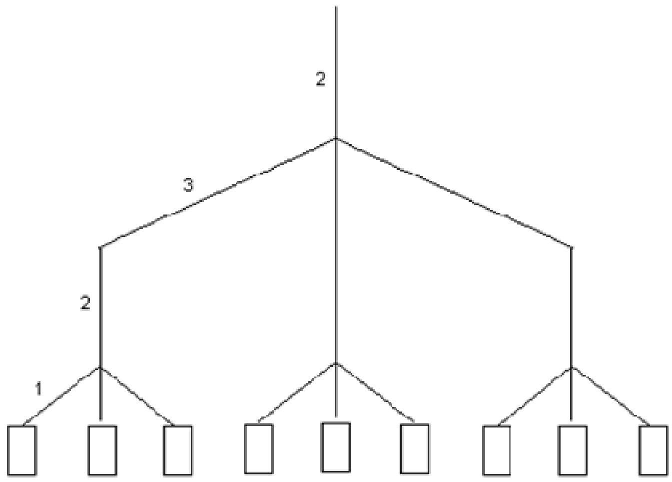
$$I_+ = \{i : f_i \geq 0\} \quad ; \quad I_- = \{i : f_i < 0\} . (**)$$

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 whose production it wants to expand), and, conversely, which one is unprofitable (and whose production it tries to reduce). According to the model, only one

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

sector can adjust its production up or down by one unit at any given time. The sector with the shortest *sojourn time* will be the one to jump first (because of path dependence). And so dynamics are only determined by the transition rates in continuous-time Markov chains. Distance between different sectors is defined by using ultrametric distance. Therefore, the economic environment is structured as a tree diagram in which every sector is a "leaf" which is connected to the rest of the tree through "nodes". Transmission of economic shocks in the environment depends on distance between leaves and branches. The distance is measured between "nodes" (Figure 3).

Figure 3 - Ultrametric distances



Ultrametric distance $d(i, j)$ has 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 are no 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 more possibility of being hired than workers belonging to more distant sectors. The distribution of the stochastic probability that a certain worker of a certain sector will be hired by a sector can be assessed by using the master equation. Ultrametrics can also be introduced as dummies for institutions and other kind of "special agents" whose actions can influence the system as a whole. Accordingly, the analysis can be used not only to forecast the evolutions of the system sic *rebus stantibus*, but it can also 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 the contemporary economy such as natural and environmental resources, human resources, and technology. Furthermore, incorporating these factors into the model does not increase the complexity of the mathematical instrument. This specific issue is broadly analysed in the next section.

Economic Policies in Spatially Extended Systems: New Paradigms

Description of the evolution of spatialised economies emphasizes the role of new rather than classical paradigms. New factors seem to have replaced land, work and physical capital. Natural and environmental resources, human resources and technology are beginning to get the upper hand following the "technological revolution". Co-operation within businesses and between businesses and business systems takes place on a vertical and 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 seen in different territorial contexts. Territorial variables, in other words, are decisive factors in explaining development differentials, especially when they are associated with the idea of the market conceived as a social construction. This new market requires 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 re-assemble 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 returns) can develop through the interaction of the agents operating in it. The territorial dimension and the systemic nature of the production process are fundamental elements to understanding and governing 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. It must taking the shape, on the one hand, of a set of actions aimed at defining and guaranteeing individual access rights and, on the other , 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 government policies, 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 lose their capacity to produce the expected results when enforced in the context of an open market or of a market characterized by strong interrelations between agents, 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 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.

Planning Actions in Spatially Extended Systems: Old and New Approach

From the aforementioned concept 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 seen 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 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 *Spatially 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 interrelationships between the individuals operating within it cannot be of a deterministic kind unless part of it is isolated from the rest of the relationships.

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 characterised 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 metabolises 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&D 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.

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 neighbour 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.[13] Obviously, without agent interaction *H* and *Heff* are equal. *Heff* therefore assumes the form:

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

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

13 Heff represents the actual output of the implemented policy.

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 generalised transmission mechanism of economic policy by 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.

Some concluding considerations

The debate in economics between those who maintain that complexity and its causes play 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 by using linear and equilibrium-type models regardless of the complexity of the behaviour of agents and markets is 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 had 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.

Assessing the quality of local development through an input-output model

Introduction

After having discussed agglomeration dynamics in the global context, the essay tries to assess the *quality* of local development by taking into account two key dimensions: the (regional) industrial mix, and the level of (labour) productivity. In other words, this section discusses the qualitative patterns of regional development using the input-matrix as an instrument to understand what happens when a regional economy changes its productivity function or when, on the contrary, it retains the same productivity function. As in the case of national economies (Arrow and Hahn 1972), each individual region can be modelled as a linear input-output system to assess whether the local community has transformed its factors of production or not; i.e. whether a new production function has been implemented or not. If the region has adopted a new production function, local growth can be intended as a collective development of skills, human capital and investment capacity, which influence the sustainability of growth. Otherwise, the region is just exploiting in an extensive way its resources and factors of production. Such condition may affect the sustainability of growth, since the community is not investing its energies in developing new skills or human capital: the local community has not created *a new competitive advantage*.

As assessed above, because of globalisation many regions have achieved a remarkable growth thanks to local specialisation in a given sector or activity. This is due to international division of labour and increased factor mobility. On the one hand, in a number of regions this phenomenon has brought about the possibility of concentrating capital and labour in new sectors characterised by an high level of productivity and, thus, by an higher potential of development. In this case, the economy has gone through a process of technological transformation that impacts on (*i*) factor productivity, and (*ii*) knowledge, skills, and occupational structure of employment. This is the most desiderable pattern of development, even though in some cases the impact on the employment (creation of jobs) may be neutral.[14] On the other hand, in some regions growth depends on an extensive use of resources and factors of productions. This means that the region has not changed its productivity function or the sectoral composition of the economy. Such a pattern of growth is based on the *multiplication* of factor of production. Far to be the exception, regional development due to factor multiplication is very common also in industrialised countries that can use the large influx of low-skilled workers (e.g. immigrants coming from less developed countries), an outcome of globalisation, to improve sectors characterised by low per capita productivity such as construction, traditional manufacturing, or proximity and personal services.[15] This

14 . This phenomenon is often labelled as “job-less growth” or employment neutral growth (Gordon, 1993).

15 . Growth can occur through factor multiplication process or factor transformation process (Barewald, 1970). Factor multiplication involves increase in the quantity of the same factor inputs of the given quality to be transformed into highest output of the same type and quality

pattern of growth may lead to a paradox: that economic growth does not depend on movement from less efficient to more efficient technology, yet the higher (regional) income is associated with higher employment rate but lower productivity per capita.[16]

To evaluate the *quality* of regional development, this essay uses the input/output analysis. The input/output analysis is a method used to characterise economic activity in a given time period, and to predict the reaction of a regional economy to stimulation, for example, from increased consumption or changes in government policy. For instance, the input/output analysis can be used to describe the way in which the productive system satisfies final demand (consisting of consumption, investments and exports). An input-output matrix represents the links between an economy's resources and its consumption. The matrix may vary from the simple (three sectors: industry, services and agriculture) to the complex (over 500 branches). It is one of the only techniques applicable to the evaluation of the sectoral impacts of structural interventions, because it allows for the detailed division of an economy's productive structure. An input-output matrix can be compared to a macro-economic model that is highly simplified regarding the economic mechanisms represented, but which is extremely detailed from the sectoral point of view.

Input-output analysis is used primarily in scenario analysis and simulation, where it serves to verify policy scenarios, based on the technological structure of the economy of a given country (or region, as in this case) and on the state of final demand. Also, it can be used in predicting dynamics. For instance, there are numerous applications of input-output matrices to the evaluation of development programmes, including estimating impacts differentiated according to the different branches of an economy. Following the aim of this essay, the input-output analysis will be used to assess the typology (or, as stated above, the *quality*) of regional development.

Input-output matrices are based on the notion that the production of outputs requires inputs. These inputs may take the form of raw materials or semi-manufactured goods, or

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through the use of the same production function. But the factor transformation process involves a different production function resulting in more and different quality output per unit of factor inputs. New production function generally embodies different technology. Technology affects the nature, direction and magnitude of relationship between employment and income. Development of technology has generally been capital intensive and labour displacing, and hence, labour augmenting. Besides, new technology is often more knowledge and skill intensive. Knowledge and skill requirements are not only greater in magnitude and superior in quality but these are also very different from earlier ones. This makes some occupations and types of knowledge/skills redundant and obsolete, while some new occupations and types of education emerge

16 . Classical economics states that economic growth is generally characterized with a movement from less efficient to more efficient technology (Mathur, 1962). The technological change leads to growth of income, through improvements in employment and productivity. However, technological development has generally been capital intensive and labour displacing. This may lead to a paradox: on the one hand, economic growth can be associated with higher productivity and income but lower employment; on the other hand, a higher income can be associated with higher employment rate but lower productivity per capita.

inputs of services supplied by households or the government. Households, provide labour inputs, while the government supplies a wide range of services such as national security, social services and the road system. Having purchased inputs from other producing sectors, or primary inputs from households, an industry then produces output and sells this output either to other industries or to final demanders, such as households or residents of other regions. Thus, a wide range of inputs is used to produce an equally wide range of outputs.

Assessing inputs and outputs through an input-output model it is possible to detect the (regional) productive specialization. For instance, the industrial mix of the region is clearly depicted by the transaction matrix and key sectors are easily detectable. Thus, if the previous part of this essay studied the agglomeration forces that concentrate factors in a given territory, this part aims at understanding whether the achieved agglomeration (i.e. the local specialization) is characterized by (*i*) a specialisation in high-tech sectors, or mature sectors enjoying a large and stable international demand, and (*ii*) a higher level of productivity.[17]

Detecting backward and forward linkages through an input-output analysis

In a regional assessment is obviously important to know how closely "linked" sectors are with each other, and which sectors may considered as the *drivers* of the economy. Of course, the direct linkages are shown in the matrix of technological coefficients (the so-called *A* matrix), and the direct plus the indirect linkages are revealed by the Leontief inverse (Mathallah, 1996). However, we need to distinguish between *backward* linkages and *forward* linkages. Backward linkages are the relationship between the activity in a sector and its purchases. Forward linkages are the relationship between the activity in a sector and its sales. These linkages may give rise to the agglomeration of activity in a given region.[18] Input-output models are based on the assumption that export demand (or the ability of industries to sell to the external economy) is the engine that generates activity in the regional economy (and the pillar of their competitiveness, cfr. Camagni, 2002). Changes in final demand (direct effects) infuse local industries with new funds, which increase output and employment.[19] The

17 . It is important to bear in mind that it is very difficult to evaluate the quantity of technology that a sector embodies. To have a clear assessment of the level of technology used by a given industry one should look at the supply-chain rather than at the sectors. Empirical evidence demonstrates that often in some mature production such as textile there are specific activities that can be considered as high tech ones. On the contrary in other sectors commonly defined like “high tech sectors” or capital intensive sectors, there are some activities that are rather labour intensive.

18 . New economic geography theory argues that although flexibility in location decisions exists a priori, once the agglomeration process has begun, spatial differences become quite rigid. Krugman and Venables (1995) and Venables (1996) have shown how this feature can be explained by backward and forward linkages. The same result of lock-in dynamics is achieved with different hipotesis as the possibility that location decisions are influenced by previous equilibria of the system, as it was stated in the first part of this essay.

19 . A sector’s outputs are demanded both inside and outside the regional economy. Final demand in an input-output framework is that portion of demand that is not used in the production of other

present essay assumes that a region with stronger backward and forward linkages in sectors with high rate of export is in a more favourable condition than a region with weak linkages in export oriented sectors (Cfr. Aoki 2002).

The analysis of linkages, used to examine the interdependency in production structures, has a long history within the field of input-output analysis. Since the pioneering work of Chenery & Watanabe (1958), Rasmussen (1956) and Hirschman (1958) on the use of linkages to compare international productive structures, this analytical tool has been improved and expanded in several ways, and many different methods have been proposed for the measurement of linkage coefficients. The measures, including backward and forward linkages, have extensively been used for the analysis of both interdependent relationships between economic sectors, and for the formation of development strategies (Hirschman, 1958). In the 1970s, these traditional measures were widely discussed and several adapted forms were put forward (Yotopoulos & Nugent, 1973; Laumas, 1976; Riedel, 1976, Jones, 1976; Schultz, 1977). Moreover, linkage analysis methods have attracted increasing attention from the part of input-output analysts (Cella, 1984; Clements, 1990; Heimler, 1991; Sonis et al, 1995; Dietzenbacher, 1997).

In this essay both backward linkages and forward linkages are taken into account. Such choice can expose the analysis to a possible criticism. There is some literature against the reliability of this methodology (Cardenete and Sancho, 2006). In fact, while backward linkages are constructed from the Leontief inverse matrix, forward linkages use the inverse matrix from the Ghosh model.[20] While the Leontief model has a clear technological interpretation well rooted in production theory, the Ghosh model lacked a corresponding embedding in standard micro theory until Dietzenbacher (1997) suggested to interpret the model as a price model. For a long time therefore, more conceptual credit has been given to backward linkages than to forward linkages since only the former were believed to trace the ripple effects implicit in the underlying technology.

The output multipliers, defined as the column sum of the Leontief inverse matrix, obviously indicate backward linkages. Using the row sums of the Leontief inverse, the output multipliers are given by $(I\text{-}A)^{-1}\, i$. This shows the effect on the total activity in each sector if every sector increases its final demand by unity. This is sometimes referred to as "sensitivity" of the sector. This is true if we assume that intermediate inputs are proportional to total output. Otherwise we would assume that intermediate flows are supply led rather than demand led. For most economies this is a less acceptable assumption (Matallah and Proof, 1994).

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outputs inside the regional economy (intermediate demand). Final demand includes consumption, investment, government and exports.

20 . Ghosh's “supply-driven” input-output model is a well-known alternative for Leontief's traditional “demand-driven” input-output model. The Ghosh model calculates changes in gross sectoral outputs for exogenously specified changes in the sectoral inputs of primary factors. Typically, the model is interpreted so as to describe physical output changes as caused by changes in the physical inputs of primary factors (Dietzenbacher, 1997).

The backward linkages of each given sector represented in the matrix can be represented as an index derived by the *i*th(s) sectoral multipliers. In this case, the result is an index in which z_{ij} is an element of $(I\text{-}A)^{-1}$(*). The index is constructed to measure the relative strength of the backward linkages by dividing each of the sectors' backward linkages by their respective averages for the whole economy.

$$n\sum_i z_{ij} / \sum_j \sum_i z_{ij} \qquad (*)$$

Concerning forward linkages, rather than using the inverse matrix from the Ghosh model (see above) and assuming that intermediate inputs are proportional to total output, one might assume that they are proportional to total inputs (Jones, 1976); i.e. rather than using

$$x_{ij} = a_{ij} X_j$$

we might use

$$x_{ij} = b_{ij} X_j.$$

This means that the intermediate flows are supply led rather than demand led. Therefore, if the matrix (B) is defined as above, then the row sums of $(I\text{-}B)^{-1}$ are measures of forward linkages. In other words, thanks to this method it is possible to define forward linkages by using the Leontief inverse matrix. Accordingly, the "input multiplier" (that is the result of our assumption) will generate the index (**) measuring the intensity of forward linkages per each sector:

$$n\sum_i q_{ij} / \sum_j \sum_i q_{ij} \qquad (**)$$

where q_{ij} is an element of $(I\text{-}B)^{-1}$.

Finally, these indexes can be used to measure the relative strength of the forward and backward linkages within the regional economy. Sectors possessing weak forward linkage indices meant that these industries sell their output mostly to final demand and hence do not figure significantly in the measures as they depend on intermediate flows. Sectors possessing weak backward linkage indices meant that their dependence on other sectors for their inputs is relatively low, i.e., their principal inputs are provided mainly by imports. Key sectors, according to Hirschman (1958), are those sectors with both backward and forward indices greater than unity. However, it is possible to consider some nuances rather than a dicotomic approach (Matallah, Proops, 1996).

A numerical application of these indexes and a calculation of the strengths of linkages within the regional economy is presented in the last part of the essay, where the case of the Madrid metropolitan region will be analysed through this *lens*.

On the relationship between the labour productivity and employment

Before discussing the measurement of labour productivity through an input-output model it is important to highlight the relation intercurring between labour productivity and employment. Employment has become an increasing concern. The concept of "jobless growth" has emerged as the focus of debate both among analysts and policy makers (Bailey and Lawrence, 2001). Employment income-growth interrelation cannot be a homogenous phenomenon across the sectors, over space and through time; nature and degree of this relationship is bound to vary among sectors. Probably the nature of employment, specially its knowledge and skills profile, has undergone radical transformation. *A priori* reasoning suggests the tertiary activities to have emerged as the dominant generator of job opportunities. Conceptual categories, such as casual and marginal employment, knowledge, skilled, technical and professional workers have now acquired greater importance in the knowledge economy. This justifies the rising interest of regions in attracting human capital from other regions to avoid constraints to growth on the supply side of the labour market.[21]

Above we have assumed that if growth is due to *factor transformation,* local development will be sustainable on the long-run. Such hypothesis will be maintained in this section, even though some specifications are needed. Enhancing the local knowledge-base means to improve the use of some given factors such as skilled labour. However, especially at the very beginning of the *transformation* process, new sectors are not able to absorb that part of displaced workforce coming from low tech sectors, thus local development is often neutral to employment. In the case of *factor transformation* the new workforce is more, better and differently educated. Human capital, which is the human resource deployed on productive work, embodies different knowledge profiles to match the changing industry-occupation structure as the economy moves from lower to higher stages of growth. Therefore, transformation of both the local industrial mix and human resources take places. The replacement of the old by new technological transformation of production may involve knowledge, skills, industry and occupational production function through the change in technology and may adversely impact employment in the process of growth of income.

Although neutrality to employment should be transitory (positive effects should arise when local workforce reach an high level of specialization and, of course, when the high tech sectors are sufficiently developed), the presence of a large number of semi or unskilled workers tossed out from the labour market is likely to challenge local development. On the contrary, the large increase of the employment rate that goes hand in hand with the *factor multiplication growth* is likely to have a positive effect on the

21 . This concept is close to that discussed by Richard Florida (2002). According to Florida, the key resource of contemporary economy is the so called "creative class". Regions have to offer a large series of advanced services and amenities to concentrate a high level of such creative class. For another approach to workers' preference for amenities Cf. J. Roback 1988.

overall economy. Because of such characteristics, place-based policies point often at increasing employment more than specialization in knowledge intensive sectors.[22]

The *factor transformation* process through technological improvement may be envisaged to have three different impacts on employment; (*i*) *employment less growth*; (*ii*) *employment loss growth*; and (*iii*) *employment gain growth* (Barewald, 1969).

The use of technology of different vintages in regions implies the simultaneous operation of *factor multiplication* and *factor transformation* processes of growth. It is, therefore, probable that all three types of employment effect of growth are manifested as the economy moves from lower to higher stages of growth. Within each broad sectoral category, some sub sectors tend to stagnate and even decline, while some others emerge as fast growing/leading sectors of development within the given category; growth may carry different employment implications for different sectors. Some more knowledge intensive sectors, may register employment gain, whereas the employment loss of other sectors may swamp this gain.[23] In other words, a trade-off between productivity and employment is likely to exist. Therefore, the thesis that *liberalization*, *privatization* and *globalization* has resulted in *employment less growth* may be empirically and logical valid in a macro sense.

Measuring per capita productivity to detect a factor transformation process: the input-output model

The nature of local development can be detected by measuring (labour) productivity gains at the regional level. There are many ways to measure productivity (OECD, 2001). The choice between them depends on the purpose of productivity measurement and, in many instances, on the availability of data. Broadly, productivity measures can be classified as single factor productivity measures (relating a measure of output to a single measure of input) or multifactor productivity measures (relating a measure of output to a bundle of inputs). Another distinction, of particular relevance at the industry or firm level is between productivity measures that relate some measure of gross output to one or several inputs and those which use a value-added concept to capture movements of

22 . It is the case, for instance, of policies that improve flexibility in the labour market. The aim is to improve the activity rate allowing low skilled to join the labour market. Although the effect on growth can be neutral, the advantage is to increase overall productivity, while the effect on per capita productivity is likely to be negative. To overcome such productivity loss policies improving labour market flexibility should be coupled with policies aiming at increasing human capital (for instance, by increasing schooling). In a global economy, the prosperity of a region depends on the skills, knowledge and intellectual capital of those capable of creating and fostering innovations. In this scenario, education becomes central to economic policy because it is through education that knowledge revolution can take place.

23 . It is worth to note that this dynamic is the same that was assessed in the first part of the essay. In a economic-system where all components are linked, the sectors that are enjoying a positive dynamic tend to attract resources from other stagnant sectors. The overall result will depend on the intensity of growth in driving sectors, which in turn depends on their position within the global market (Cfr. Aoki, 2002).

output. Using these criteria to enumerate the main productivity measures it is possible to enumerate measures of labour and capital productivity, and multifactor productivity measures (MFP), either in the form of capital-labour MFP, based on a value-added concept of output, or in the form of capital-labour-energy-materials MFP (KLEMS), based on a concept of gross output. Among those measures, value-added based labour productivity is the single most frequently computed productivity statistic, followed by capital-labour MFP and KLEMS MFP. These measures are not independent of each other. For example, it is possible to identify various driving forces behind labour productivity growth, one of which is the rate of MFP change. This and other links between productivity measures can be established with the help of the economic theory of production.

The choice of the way in which measuring productivity will depend on the suitability of each index to the main purpose the researcher has in mind. Whenever the aim is to measure competitiveness, as in this case, the proper measure will be the inverse of the total labour embodied in one unit of final product; or, what amounts to the same, the labour employed in the vertically integrated sector corresponding to each final good. Considering labour as the only factor of production, the entire output of the economy is attributed to it.

The model

Let's consider to have a time series of transaction matrixes (Prakash, Balakrishnan, 2005). In this case data coming from transaction matrix will be taken into account to measure local factor productivity.[24] It is postulated that total output, X equals the product of total employment, N and average productivity, P:

$$X = P * N \tag{1}$$

X is GDP at factor cost in t_0 prices. Differencing the equation partially, we get

$$dX= dP * N + dN * P + dP * dN \tag{2}$$

First term of this equation measures the effect of income growth due to change in productivity, when employment is constant, second term determines employment effect of income growth with constant productivity, and the last term determines the interaction effect of change in employment and productivity in response to the given change in output. Interaction effect may be distributed between employment and productivity effect exactly in proportion to the shares of first and second terms in overall growth. Division of equation (2) by X yields

24 . An increasing number of regions have started producing input-output matrix of their economy. This is due to the devolution of administrative power to local governments. They need to improve analytical tools to set up policies.

$$dX/X = (dP / P + (dN / N) + \{dP / P\} * \{dN / N\} \qquad (3)$$

This also is expressed as

$$G_x = G_p + G_n + G_p * G_n \qquad (4)$$

G_x is the rate of growth of income, G_p is the rate of growth of productivity and G_n is the rate of growth of employment. The model can also be modified as follows in order to estimate the relative shares/contribution of productivity and employment growth in the growth of income.

$$\{G_p / G_x\} + \{G_n / G_x\} + \{(G_p * G_n) / G_x\} = 1 \qquad (5)$$

To capture both the direct and indirect repercussions of growth of income on employment and productivity, Input Output model has been used to determine output, *X*:

$$X = (I\text{-}A)^{-1}F \qquad (6)$$

X is the column vector of gross output, A is matrix of technical coefficients of production, $a_{ij}\ \varepsilon\ A$, $(I\text{-}A)^{-1}$ is Leontief Inverse, and *F* is final demand. Employment involved in the production of this output may be given by

$$\hat{N} = LX \qquad (7)$$

$\hat{N}$ is a column vector of sectoral employment. This will also furnish an idea about the sectoral composition of total employment. *L* is a diagonal matrix of employment coefficients, a_{oi} where

$$a_{oi} = L_{oi} / X_i$$

is labour required per unit of output, $\sum_i L_{oi}$ is total employment in the economy. Substituting for *X* from (6) into (7), we get

$$\hat{N} = L\ (I\text{-}A)^{-1}F \qquad (8)$$

Recalling what we have stated above, net productivity may be estimated by working out the ratio of factors used in production and net output (value added) which is given by V_j/l_j; where

$$l_j = a_{oj} * \Sigma a_{ij}$$

and V_j is the value added per unit of output. The gross factor productivity $\hat{P}$ is given by

$$\hat{P} = L^{-1}X \qquad (9)$$

where $\hat{P}$ is sector wise column vector of productivity $p_j = X_j/L_{0j}$. The following relation shall furnish the estimates of productivity

$$\hat{P} = \hat{A}_0 X^{-1} = L\,(1 - A)^{-1} \qquad (10)$$

where P` is the sector wise column vector of productivity, and $\hat{A}_0$ is a diagonal matrix whose elements are $A_{01}, A_{02}, A_{03}, \ldots A_{0i}$.

$$1/a_{oj} = p_j$$

is the direct/partial estimate of productivity. If A_{0j} denotes total labour required per unit of final demand, then

$$1/A_{0j} = \hat{p}_j$$

will be the total labour productivity. Use of solution rather than observed value of X in the above formula is an attempt to (i) consider both direct and indirect requirement of labour for production (ii) direct and indirect requirement of capital. The capital requirements are embodied as a component of final demand which comprises both Gross Fixed Capital Formation (GFCF) and change in stocks (Juan and Febrero, 2000) and (iii) requirements of growth, since growth is financed out of surplus. This is taken into account by matrix *A*. This surplus feeds the multiplier process through consumption while accelerator is taken care of through change in stock reflecting working capital requirements and fixed capital formation part of final demand. As stressed above, productivity index is here used to evaluate the competitiveness of a given industry in a given region by X_j/L_{0j}, which is the conventional measure of productivity (Juan and Febrero, 2000). The growth rates of sectoral productivity are given by

$$G_p = \Delta \hat{P} . \hat{P}^{-1} \qquad (11)$$

$d\hat{P}$ is the row vector of change in sectoral productivity, G_p is the vector of productivity growth rates, and $\hat{P}^{-1}$ is a diagonal matrix of initial levels of sectoral productivity. Following equation yields the estimate of sectoral employment growth:

$$G_n = d\,\hat{N}\,N^{`-1} \qquad (12)$$

dN is the row vector of change in employment, G_n is the vector of sectoral employment growth rates and $N`$ is the diagonal matrix of sectoral employment levels. Growth rates of sectoral output may be derived analogously:

$$G_x = d\,\hat{X}\,X'^{-1} \qquad (13)$$

$d\hat{X}$ is the row vector of change in output and X' is the diagonal matrix of initial output. It is implicitly assumed that the change in output $d\hat{X}$ embodies the effect of change in i) technology, ii) human capital, iii) policy regime, from all the period of the series. In this way it is not necessary to build a capital coefficient matrix. There is still the problem of isolating the effect of change in technology from other components of change (Solow, 1962):

$$X_t = (I - A_{t-1})^{-1} F_t \qquad (14)$$

t refers to the current period. The use of the preceding period's I-O table to estimate X_t from relation (6) nullifies, in part, the change in technology. Similarly, the effect of change in final demand may take the form of:

$$X_t = (I - A_t)^{-1} F_{t-1} \qquad (15)$$

Differential output of 6 and 13 will furnish estimates of differential employment and productivity levels due to the difference of technology. As against this, differential of output of (5) and (13) will reflect the effect of change in final demand, which may manifest the human capital effect on employment.

A complication: the offsetting effect of increasing final demand on labour productivity measurements

According the model discussed above when the vector of final demand is held constant, technical improvement will result in an increase in the level of measured labour productivity at both the aggregate and sectoral level. Technical change is here considered as reduction in one or more input-output coefficients with no increases in any input-output coefficients. It is worth recalling that reductions in input-output coefficients can be due to a number of reasons apart from technical improvement as, for instance, economies of scale, substitutions induced by changes in relative input prices, and changes in sectoral product mix (Galatin, 1988).

Taking into account two different periods and maintaining the same vector of demand X_F, it is possible to verify that the improvement of technical coefficients (lower coefficients in the LIM) generates an increase in labour productivity.

$$X_t = (I - A)^{-1}{}_t\, X_F$$

In the equation above the output X at t is derived from the LIM multiplied by the aggregate demand. If there is a technological improvement, the LIM (will be reduced (I - $A^{-1}{}_t$ < I - $A^{-1}{}_{t+1}$), and with the same aggregate demand X_F, the output X at time t+1 will increase, as shown in the eqation below.[25]

$$X_{t+1} = (I - A)^{-1}{}_{t+1} X_F$$

Let *p* be the n * 1 vector of prices of the outputs in the *n* sectors. Then aggregate value added, *V*, is given by

$$V = p' X_F \qquad (16)$$

V may be assumed to be identical to gross domestic product (GDP) originating in the private business sector. Total labour input, L, is

$$L= a_0 X = a_0 (I\text{-}A)^{-1} X_F \qquad (17)$$

Then the measure of aggregate labour productivity in that part of the economy covered by the input-output model is

$$\theta = V/L = p' X_f / a_0 (I\text{-}A)^{-1} X_F \qquad (18)$$

This is value added per unit of labour in the private business sector. The first problem we will examine is how technological improvement affects the level of the aggregate measure of labour productivity defined in Equation (18). Technological improvement, hereafter called technical change, will be reflected in a decrease in one or more of the input-output coefficients in the technical matrix A, and/or in the elements of the vector of unit labour requirements, a_0, a reduction in intermediate and/or the primary input, labour, required for production. Thus, if *t* indicates time, technical change is formally defined here by the condition that

$$dA/dt < [0] \qquad (19)$$

which implies that $d(I – A)/dt > [0]$, and/or that

$$d_0/dt < [0] \qquad (20)$$

Inequality (19) means that

$$da_0 / dt \leq 0$$

for all terms a_{ij} and that

$$da_{ij} / dt < 0$$

25 . The elements of (I-A)-1 must be non negative, for they represent the increases in gross outputs required for unit increases in the amount of final demands.

for at least one term a_{ij}. Similarly, the inequality in (20) means that

$$da_{0i} / dt \leq 0$$

for all i and the inequality holds for at least one i. To see how technical change affects the level of measured labour productivity, we differentiate both sides of (18) with respect to t with the level of prices assumed constant.

Differentiating the logarithm of aggregate labour productivity, θ, in Equation (18) with p constant, we have

$$\dot{\theta}/\theta = \dot{V}/V - \dot{L}/L \tag{21}$$

where a dot above a variable, be it a scalar, vector, or matrix, indicates its derivative with respect to time (Galatin, 1988). Now from the derivative of L in Equation (17), we find that

$$\dot{L} = a_0 T^{-1} \dot{X}_F + \dot{a}_0 T^{-1} + a_0 \dot{T}^{-1} X_F \tag{22}$$

Where $T = (I - A)$.

Since, for any non-singular matrix, Q,

$$\dot{Q}^{-1} = -Q^{-1} \dot{Q} Q^{-1} \tag{23}$$

Considering $(I\text{-}A) = T$, $\dot{L}$ becomes

$$\dot{L} = a_0 T^{-1} \dot{X}_F + \dot{a}_0 X_F - a_0 T^{-1} \dot{T} X \tag{24}$$

Then substituting (24) in (21) and noting that

$$\dot{V} = p' \dot{X}_F$$

It is possible to find that

$$\dot{\theta}/\theta = p' \dot{X}_F / V - a_0 T^{-1} \dot{X}_F / L - \dot{a}_0 X / L + a_0 T^{-1} \dot{T} X$$

This equation can be rewritten in the following form

$$\frac{d\theta / dt}{\theta} = \frac{dV / dt}{V} - B_0 - (B_1 - B_2) \qquad (25)$$

Where $(dV/dt)/V = p'(dX_F/dt)p'X_F$

$$B_0 = a_0 T^{-1} (dX_F / dt) / L$$

$$B_1 = a_0 T^{-1} (da_0 / dt) X / L$$

$$B_2 = a_0 (dT^{-1} / dt) X_F / L = a_0 T^{-1} (dT / dt) T^{-1} X_F / L$$

The variable on the left-hand side of Equation (25) is the proportional rate of growth in aggregate labour productivity. The equation shows that it can be decomposed into four terms:

$$(dV / dt) / V$$

is the actual rate of growth of aggregate value added due to a change in the vector X_F of final demand (since prices, p, are held fixed throughout). The second term, B_0, is the proportionate change in aggregate labour input that would occur due only to the change in X_F with technology, the a_0, vector and the T (hence A) matrix, held fixed. Thus, the first two terms on the right-hand side of (25) depend on shifts in final demands, X_F, assuming that technology is held fixed, and are zero if final demand is constant.

The third term, B_1, is the proportionate change in labour input that would be caused by a change in the vector of unit labour requirements a_0, alone, with X_F and T (hence A) assumed fixed. Finally, B_2, is the proportionate change in unit labour requirements caused by a change in T (hence A), but with a_0, and X_F assumed constant.

With technical change, - $(B_1 – B_2)$ is positive and if final demand X_F remains unchanged, the first two terms on the right-hand side of Equation (25) are zero. Hence, if the vector of final demands remains constant (that is $dX_F / dt = 0$), then technical change results in an increase in the level of measured aggregate labour productivity.

However, when the vector of final demand changes throughout the periods, it may generate the paradox that, in spite of the reduction of coefficients, *the aggregate value of productivity decreases over time*. In fact, if the vector of final demands, X_F, changes and there is technical change, the sign of $(dV/dt) / V – B_0$ in (25) may be positive, negative, or zero, while - $(B_1 – B_2)$ is positive. Therefore, If the vector of final demands changes (that is, $dX_F / dt \neq 0$) and there is also technical change, then *the level of aggregate labour productivity may increase, remain unchanged, or decrease.* Thus, if final demands shift, technological change need not lead to an increase in the level of measured labour productivity.

How to define a Functional Urban Region

Introduction

Defining the unit of analysis is a basic step when assessing the performances of a given region. Often the administrative boundaries of a region do not correspond to its functional region. This part of the essay presents various methodologies to define the functional region; i.e. the portion of territory home to the economic and social interaction of a given homogeneous community. The main conclusion is that, according to the availability of data, there is a trade-off between "defining" (delimiting the exact portion of territory in which all the socio-economic interaction take place) and "measuring" (assessing the quality and quantity of the socio-economic interactions within the functional area).

Different methodologies and approaches

Before assessing international competitiveness of a given metropolitan region, it is important to find a standardised definition of Functional Urban Region (FUR) and using it to benchmark metro-regions with each other. In fact, the lack of a shared definition of FUR represents a big obstacle to comparative analysis of metro-regions' competitiveness. Different essays show different results because they use different definition of FURs. Broadly speaking there are three different ways to define metro-regions:

1. **The administrative approach** defines metropolitan regions based on the legal or administrative boundaries of municipalities or equivalent entity, or sometimes a group of municipalities under a regional government. This approach is typically used by the national administration to structure, organise and rule the country.

1. **The morphological approach** defines metropolitan areas taking into account the extent and/or continuity of the build-up area, the number of inhabitants, and proportion of the municipal areas covered by urban settlements. The morphological approach, independent of political boundaries, is an efficient way of defining the visible city for inhabitants, especially from satellite or aerial view.

2. **The functional approach** defines a Metropolitan Regions based on daily commuting flows between a core area – that might be defined according to morphological or administrative criteria – and the surrounding territories. Analyses of commuting flows determine which areas are included (or not) in the Metropolitan Region.

Each definition out of the three tends to be better suited for specific purposes but not for others. For instance, an administrative definition would probably be appropriate for analysing governance issues within a metropolitan region such as fiscal policies. In contrast the morphological approach is better suited to analyse or define zoning, environmental issues, and housing development policies. Nonetheless, it does not takes into account all those people living out of the realm of the city but depending on it for their work, public service delivery, or leisure consumption. Interaction out of the built environment are well detected by the functional definition which will be used here for analysing socio-economic problems such as infrastructure and transportation, traffic congestion, labour market analysis, and inter-linkages of firms. However, within the functional approach one can use different methods to define the FUR. Broadly arguing, they are the *two components model* and the *partitioning method*. They will be discussed in turn below.

The two-component model

In the *two-component model* a metropolitan region is conceived as an area containing a large population core and adjacent communities (building blocks) with a high degree of integration with the core. The degree of integration is generally measured by commuting flows between the adjacent communities and the core area. The first step of the model, therefore, consists of selecting the core, also called city-core or nucleus, which can be defined on administrative, morphological (i.e. build up area), functional or a combination of these criteria.[26]

In the second step, the Metropolitan Region is expanded to surrounding areas that have a high degree of integration with the core. The size of these "building blocks" differs from one definition to another.[27] The degree of integration – between the core and

26 . For example, the core of the Urban Audit (Eurostat) for European countries is administrative and corresponds to a local government unit with the political function (i.e., a council and a mayor). In most EU countries, this administrative core is typically composed of a LAU 2 region (e.g., municipality or "commune"). Greece Ireland, Portugal and the UK are exceptions to this general rule, as the core corresponds to a LAU 1 region (i.e., an aggregation of LAU 2 regions). In addition, the core city in France, Cyprus or Malta is composed of a group of municipalities – all engaging in joint co-operation to deal with urban issues – instead of a single municipality. This is widely recognised to be an interim measure pending a more economically robust definition of the core, imposed by the requirement of collecting an initial benchmark set of statistics within an acceptable time frame. In contrast to the Urban Audit, the core of the GEMACA (Group of European Metropolitan Area Comparative Analysis) definition for European countries is functional and is defined as a contiguous area of adjacent LAU 2 municipalities with an employment density of at least seven jobs per hectare. For the case of the US and Canada, the core is both functional and administrative. The administrative component corresponds to the choice of counties for the US and municipalities for Canada; as for the functional component, the counties in the US must have at least 50% of their population or 5 000 persons residing in an urbanized area while the municipalities in Canada must have over 75% of the population living in the urban area. The latter is defined in both cases according to a population density threshold (500 persons per square kilometres in the US and 400 in Canada) and minimum population requirement (2 500 in the US and 1 000 in Canada).

27 . In Eurostat's definition, the building blocks match to NUTS 3 or LAU 1 regions, with the exception of some northern and central European countries which use LAU 2. These latter countries use a nominally smaller regional unit since recent reforms in their local government have reduced the number of municipalities. In the GEMACA definition, the building blocks are

adjacent communities – is measured through a commuting ratio capturing the percentage of the employed population (or labour force) of the adjacent communities that work in the core. If the commuting ratio is above the specified threshold, the adjacent community becomes part of the Metropolitan Region.[28] Most National Statistical Offices (NSOs) have used the two-component model, or an offspring of it, to delineate Metropolitan Regions. This method is well suited for monocentric metropolitan structures characterized by a single city core and surrounding zones of influence.

On the one hand the two components model has the great advantage of being a statistical method is easy to implement; on the other hand it has four major shortcomings:

- First of all, such method may lead to low international comparability due to the different size of the building blocks (due to different statistical definitions).[29] However, some preliminary results of sensitivity analysis suggest that the size of these differences may be smaller than expected.[30]

- Second, results change according to the criteria used to select the core regions, *i.e.*, administrative or functional. For instance, in the cases of Eurostat and ESPON, the core is selected according to an *administrative criterion* (*i.e.*, a city-core) with a minimum population threshold while in the case of GEMACA (2002) it is selected using a *functional criterion* (*i.e.*, six jobs per hectare). In general, whether one criterion should be preferred to another will depend of the purpose of the definition. However, one would expect the choice of one criterion

municipalities, while in the US the building blocks match to the county level and in Canada to the municipality level.

28 . In Eurostat the threshold level, measured by the number of commuters to the city-core to resident employed in the municipality, was tested applying two thresholds: a narrow commuting field of 20% and a wider commuting field of 15%. In GEMACA's definition the threshold stands at 10% of their economically active population working in the economic core. A common trend identified in the US and Canadian definition reveals that jobs are also created in the fringes in addition to the core therefore both definitions use counter-commuting ratios from the core to the fringes and vice-versa. The forward commuting ratio in the US is lower (25%) than in Canada (50%). The backwards commuting ratio in both cases is set at 25%.

29 . In general, US counties are larger than Canadian municipalities while European regions are either too large (NUTS 3) or too small (LAU 2) in comparison to US counties and Canadian municipalities. Only the municipalities in Northern Europe seem comparable with Canadian municipalities in size. Therefore, the size of the building blocks in Europe do not match those of the US and Canada. The same is true also for the size of the core.

30 . For instance, Alan Freeman (2004) compared the frequency distribution of the sizes of US counties and European NUTS 3 regions. The frequency distribution turned out to be more uneven within the US than between the US and Europe. In particular, a much higher proportion of US counties are rural or settled at a low population density. 83 per cent of US counties have a population of less than 100, whilst 76 per cent of NUTS3 areas contain a population greater than 100. To some extent this arises because the US contains much more rural or sparsely-settled territory than Europe, in relation to its size. The discrepancy is much smaller if only urban counties and NUTS3 areas are considered: 19 per cent of US urban counties contain less than 100 people compared with 13 per cent of NUTS3 areas.

to have a significant impact on the international comparability of Metropolitan Regions.[31]

- The third shortcoming is the usage of different thresholds (*i.e.*, commuting ratios) to expand the building blocks around the core. Different definitions use different threshold values. Furthermore, definitions in the case of Europe use a one-way commuting ratio (in-commuting to the core) while in the case of North America they use a two-way commuting ratio (in-commuting to + out-commuting from the core). In Europe the threshold value varies among the definitions.[32]

- Lastly, the two-component model is inadequate to identify Metropolitan Regions with a polycentric structure. The two-component model assumes a monocentric structure with one city core and its adjacent zone of influence. This model is inadequate for polycentric metropolitan structures. In these circumstances, the partitioning method is better suited.

Partitioning the National Territory into large self-contained regions (Labour Market Basins)

The partitioning approach is a two-step method: in the first step the national territory is divided into mutual exclusive and completely exhaustive regional units that are large enough to justify separate recognition and strong self containment, enough to be relative autonomous according to internal patterns of flow; the second step is about determining which of the self-contained regions are metropolitan regions. Unlike the two-component model, the partitioning method does not predefine a city-core. Instead, it first partitions the national territory into strongly self-contained economic regions according to interactions of flows between building block areas, and afterwards it determines which of these regions are metropolitan. The criteria for what is a “self-contained labour market” are of course crucial. This second method makes use of more sophisticated tools and has emerged with advances in computational resources. In principle, these tools would be

31 . Again, preliminary results of sensitivity analysis suggest that the size of these differences may be smaller than expected. For instance, Alan Freeman compared the size of the London core in the US system and GEMACA, by changing the core from four hectares (1 000 per square mile) to 9-10 hectares (2 500 per square mile). His findings suggest that the population of the core changes substantially but the changes in the total population of the Metropolitan Region were pretty small (between 2-4%). The residential population of the core using the US threshold of 1 000 is 7 959 000 and 5 617 000 – 30 per cent smaller – using a threshold of 2,500. Applying the GEMACA threshold yields 6 944 000. For the FUR as a whole the figures are 13,310,000 for the US threshold, 12,766,000 for the GEMACA threshold and 12 407 000 for a threshold of 2 500.

32 . Eurostat uses two distinct commuting ratios to their definition: a wider threshold of 15% and the narrow one of 20%. In GEMACA's the threshold is set at 10%, and ESPON applies different thresholds to different countries (10% for Norway, 20% for Finland, and 40% for France). In North America, the US definition applies a 25% forward commuting (in-commuting) ratio to their definition while in Canada it is set at 50%. The back commuting ratio (out-commuting) in both cases is set at 25%.

capable of measuring complex interactions of flows both in the form of physical mobility (*i.e.*, commuting, chained school-shop-work trips, etc.) and in electronically-mediated interactions (*i.e.*, teleworking). In practice, the criterion to delineate the autonomy of a region is based on commuting patterns since data for commuting are widely available. The partitioned regions that are strongly self-contained can be identified as *labour market areas*. When commuting data are not available there are computer-routines that estimate the commuting flow using micro-data on employed people (at home) and jobs (at the workplace). Therefore, this method measures by construction a *functional labour market basin (catchment area).* Under certain conditions, such labour market basins may be used as proxies for *functional Metropolitan Regions*. Advantages of the partitioning method over the two-component model include flexibility in relation to building block areas, and not relying on predefined cores. This is why the partitioning method is better suited for international comparisons: it is transferable and adaptable between countries with different urban systems, commuting patterns, datasets and building block areas. In addition, it is better suited to delineate Metropolitan Regions with polycentric structures as it allows for monocentric or polycentric regions to emerge equally. But there is a risk that vast areas with too many centres are coalesced into single basins, in particular if there is circular or sequential commuting along chains of cities or if there is a high degree of commuting in all directions in a densely populated country. The main shortcoming of this method, however, lies in its dependence on computing algorithms and the availability of commuting flow data to partition the territory into self-contained economic regions. In particular, to reach international comparability the partitioning method would require that the same thresholds for self-containment are used in all countries. With modern computing facilities this is not a heavy task in computational terms, but does require suitable data in all countries.[33]

The trade-off between defining and measuring FURs

Having discussed the analytical tool, it is now possible to actually define in a normative way a metropolitan region as an *urban economy whose boundaries define a portion of territory which is both self-contained and homogeneous at the same time*. Of course, besides the accurateness of the definition, it is of a paramount importance of having statistical data corresponding to the associated area. Regional statistics are commonly available for administrative or statistical units rather than according to "functional" boundaries, e.g. commuting zones, school districts, etc.

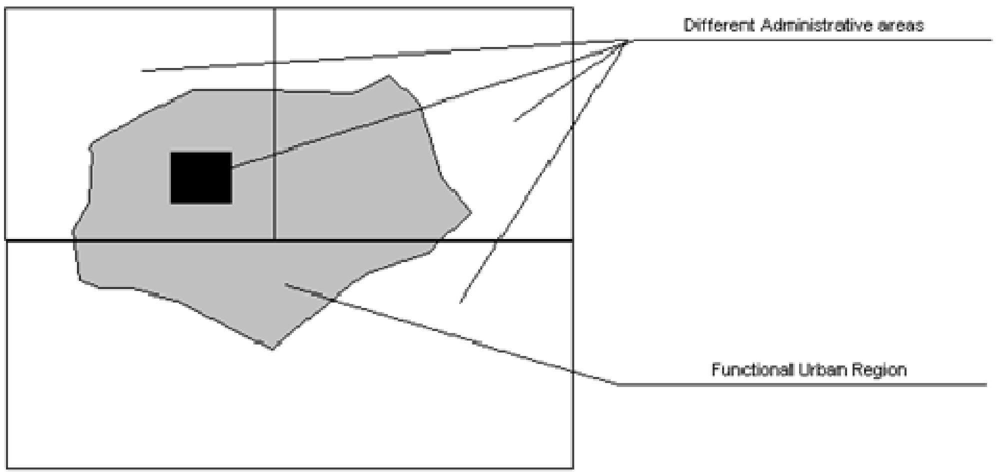
There are a wide range of projects that recognize the importance of collecting data at the boundaries of administrative cities and towns. Elected officials and local administrators are service providers to the residents of cities and town. Therefore the availability of data within administrative boundaries permits to measure their performance and the quality of the services they provide. For example the UN-Habitat developed the Large Cities Statistics Project (LSCP) questionnaire together with five

33 . Another minor short-coming is that, although the definition of a metropolitan region based on the partitioning method is independent of the regional grids specific to each country, regional data are often available for administrative regions only.

partners including the United Nations Statistics Division. This project collected and harmonised data from more than three thousand cities. The outcome was the publication of 1000-cities International Yearbook of Large Cities Statistics. In Europe, the urban audit collects and harmonised data on 258 participating cities at three spatial levels, the city-core (i.e., administrative boundary), the larger urban zone (i.e., the functional boundary) and the sub-city district (neighbourhood). In the U.S. and Canada, administrative city-level data are collected by their respective census. Data for functional Metropolitan Regions are also made available in census publications as well as estimates of some indicators.

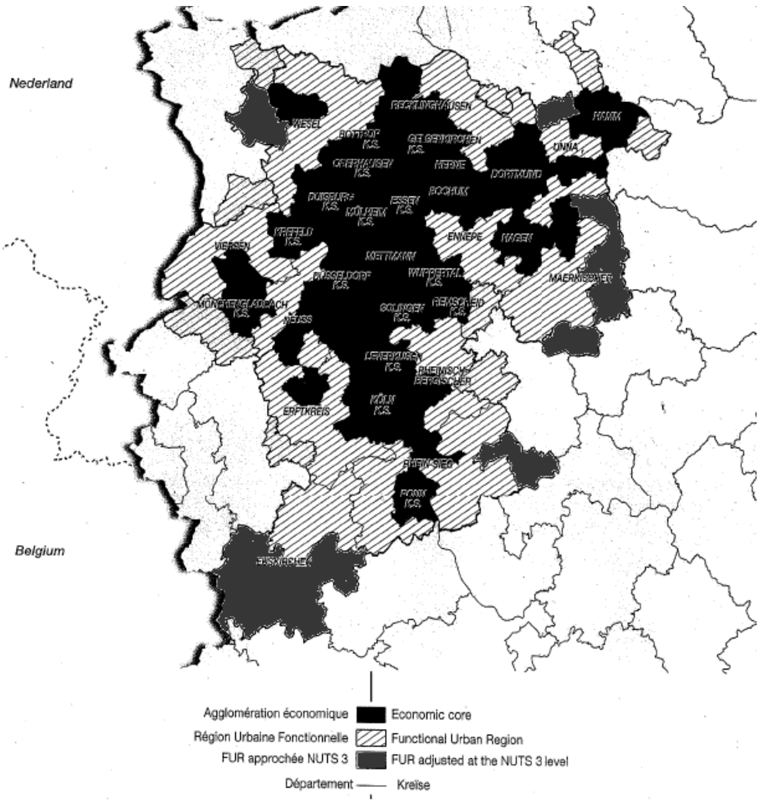
The availability of statistical figures represents the Gordian knot of any definition of Metropolitan Regions. One defining a metro-region has to take into account the availability of comparable data at the corresponding geographic levels. Figure 1 depicts the common situation where the functional borders of a Metropolitan Region vary significantly from those of the administrative region but statistics (*e.g.*, employment, GDP, etc.) are only available for administrative regions. In such cases, the theoretical distinction between the functional and the administrative definition of Metropolitan Regions breaks down when it comes to measurement. The functional Metropolitan Region is different from the administrative Metropolitan regions but only the latter can be measured (see figure 4).

Figure 4 – Functional and administrative boundaries diverge considerably



Therefore, often a trade-off emerges between the accurateness of a functional definition and the availability of data which is typically limited to the administrative level.[34] If the boundaries of the functional Metropolitan Region closely resemble to the administrative region then data from the latter can be attached to the functional area. Alternatively, some "rule" has to be applied to associate administrative regions to the functional borders. In the GEMACA project, for instance, when the majority of the population of a NUTS 3 region live in a Metropolitan Region, all NUTS 3 statistics are "attached" to the Metropolitan Region, despite the fact that the latter is smaller than the NUTS 3 region (GEMACA, 2002). This rule systematically introduces an error in the measurement of the Metropolitan Region as it overestimates all its variables. In some cases (Figure 5) the error is small but in some others (Figure 6) the approximation in hardly acceptable. Of course, one can imagine more sophisticated methods to generate estimates for functional regions based on data for administrative units. The difficulty with this approach is clearly to agree internationally on some set of procedures to estimate missing data in different statistical areas (regional account, labour force, etc.).

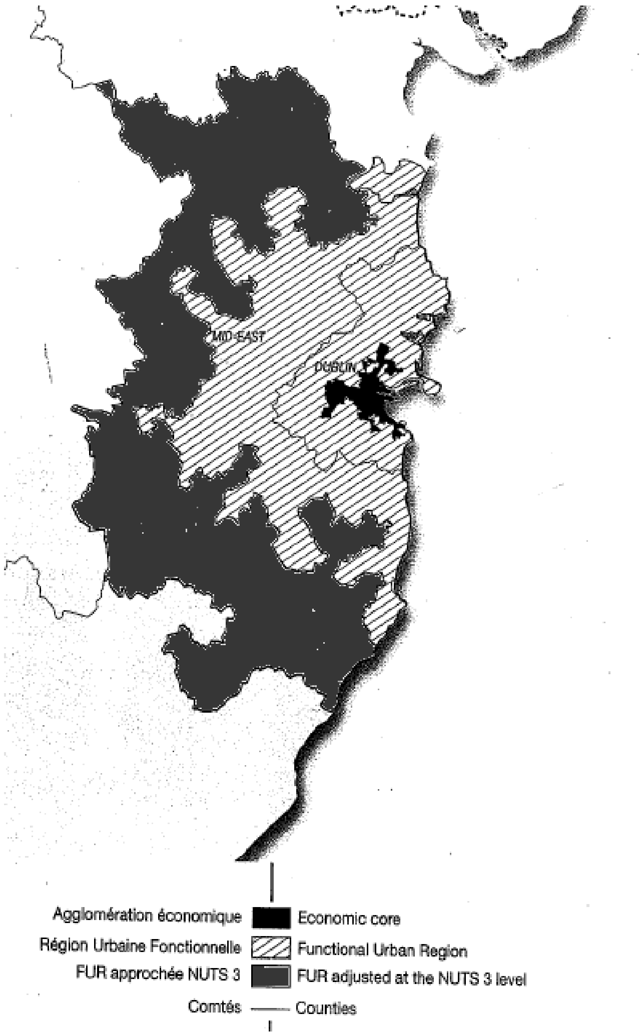
Figure 5 - GEMACA Functional Urban and Adjusted Administrative Region for Rheinruhr, 1999



Source: GEMACA 2002

34 . For instance, according to the OECD metropolitan database (OECD, 2006), administrative regions in some cases are much smaller than their Metropolitan Region; e.g., Paris, Athens, Barcelona, Copenhagen, and Milan. In other cases (Australia, Canada, Mexico, and the US) some regional data, in particular reliable GDP data, are available only for regions that are much larger than their Metropolitan Regions and only estimates are available for the functional area.

Figure 6 - GEMACA Functional Urban and Adjusted Administrative Region for Dublin, 1999



Source: GEMACA 2002