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Regional Economies and Innovative Performance as the Source of Competitiveness and Agglomeration: a System Dynamics Representation

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If anyone would like to have one or all the versions of the model, please simply contact me by e-mail.

ABSTRACT:

This article makes use of the system dynamics to argue that a number of theories about the performance of territories, developed in the past 20 years, are more complementary than alternative; to demonstrate this, a model of local economy coherent with these schools is designed and simulated.

According to these theories, the ability to produce and use knowledge is at the centre of regional competitiveness in the advanced world; the model shows the elements of the local economic system and how they have to work coherently towards the continuous process of innovation, needed to be successful.

The model also shows that, due to the cumulative nature of this innovation process, it is possible to obtain equilibria with agglomeration, even in the presence of apparently very similar territories. When this is the case, structural policies, aimed at allowing lagging regions to better innovate and imitate external knowledge, are appropriate.

Introduction

During the 80s and 90s there has been a resurgence (Storper, 1995) of interest for the issues related to space, which gained new importance in the ecomomists' works. This was in part due the observation that the Fordist method of production had not eliminated the possibility for different types of production spaces to prosper. These latter were generally composed of small and medium enterprises (SMEs) drawing from the features of their localities to become competitive on the global markets. A second observation concerned the large multinationals, which were often re-locating the production processes but at the same time were usually keeping the highest-level phases of production and invention in specific areas of the most advanced countries. Finally there was the convergence debate in its regional aspect: there is no space to enter in it here, but when the results are, at best, a conditional convergence rate of around 2% a year (Barro and Sala-I-Martin, 1991) we still perceive the world as patchwork of richer and poorer places, between nations but also within, with no plausible conjecture for an extensive levelling in the next future.

In economics, the observation of uneven development levels and the re-discovery of the Marshallian external economies led to the birth of a now well established group of theories known with the name of New Economic Geography (see the works of Ottaviano and Puga, 1998, and Fujita, Krugman and Venables, 1999); in the contributions belonging to N.E.G., various mechanisms, often but not always using the Dixit-Stiglitz (1977) monopolistic competition framework, drive to the possibility of multiple equilibria for the location of economic activities in space.

Besides the more orthodox economics, a number of theories, which will be jointly hereafter indicated, for the sake of simplicity, as 'heterodox', grew with the purpose of explaining why some local systems are more effective than others; the use of the term heterodox is justified by the fact that these contributions are resting more on case studies and descriptive models than on analytical derivations and mathematical models, and are usually more interested in the dynamics of adjustment than on the eventual equilibrium outcomes. This paper uses many concepts and drives conclusions which are comparable to these of spatial economics, but rely more on a number of ‘heterodox’ developments, which are briefly outlined below.

Among these, the industrial districts school, which completely revisited the Marshallian contribution and applied it to the Italian case, where, beyond the duality between the richer and based on the large firm North West and the lagging South, the regions of North East and Centre (NEC) had developed a dynamic economic model made of specialised districts of SMEs able to compete worldwide. These districts were characterised by (Becattini, 1990) the presence in the same area of a community of people and a community of firms, the one and the other strictly linked because of the share of common values and a number of informal economic links.

Since the ability to compete of many districts, is not only based on this flexible system of production, but also on the capability to innovate and to share knowledge in the area, the research project on Innovative Milieux was born in the 80’s with Philippe Aydalot. In the definition of Camagni (1991, p.3) the Innovative Milieu is “the set, or the complex network of mainly social relationship on a limited geographical area, often determining a specific external ‘image’ and a specific internal ‘representation’ and a sense of belonging, which enhance the local innovative capability through synergetic and collective learning processes”. The concept has evident similarities with the industrial district one, but there is a different focus of innovation: in fact the milieu is able to guarantee a continuous process of innovation diffused among the firms of the milieu itself, so that it is dynamically efficient and not only statically.

The space, in the milieu, is active and the learning process is outside the single firm but inside the milieu, this owing to a spontaneous collective learning process due to the mobility of the workforce inside the milieu, to the cooperation of firms that allows them the transfer of tacit knowledge, to the fact that risks are taken collectively, reducing the dynamic risk for the individual and therefore allowing more propensity to innovate.

Without any connection with the above theories but with a focus on the economics of innovation, the book of Nelson and Winter (published in 1982) “An Evolutionary Theory of Economic Change” gave birth to the theory called ‘evolutionary’. In the words of Dosi and Nelson (1993, p.3) “The term ‘Evolutionary’ ought to be reserved for theories about dynamic time paths, that is ones which aim to explain how things change over time, or to explain why things are what they are in a manner that places weight on ‘how they got there’”. The concepts of technological paradigm, technological trajectory and technological regimes are helpful in explaining the processes and some “unexpected” outcomes as the lock-in. In the ‘90s a number of publications, not always explicitly evolutionary, extended the analysis to the “Systems of Innovations” that is to “all parts and aspects of the economic structure and institutional set up affecting learning as well as searching and exploring” (Lundvall, 1992, p.12, ‘broad definition’). These investigations rapidly extended from the national to sub-national contexts and are often seen fully compatible with the new regional science (Cooke, Uranga and Extebarria, 1998) when aiming at explaining why different levels of regional development co-exist.

The 80’s witnesses a renewed attention to the regional economies also outside Europe. In particular, from the observation of the Silicon Valley, a theory was born in California, thanks to the works of a number of authors; among these Storper (1995) extended the analysis from the traded to the untraded interdependencies, that is from the observation of intense transactions between firms in the same space (with a mobile local workforce so that the increased flexibility allows a reduction of costs) to the observation of untraded relations, often conventional, neither fixed nor present in all times and all places but able, when present and positive, to enhance collective action and learning and, in this way, make the system more efficient.

The influence of institutions, rules and routines on competitiveness has been emphasised by many authors (e.g. Cooke and Morgan, 1998) in contributions that we could call "neo-institutionalist" and which are applied with success to a large number of cases of local production systems.

For the theory of the diffusion of knowledge and the learning mechanisms inside a territory the term "learning region" (Florida, 1995) has been introduced.

This paper argues that these heterodox schools of thought should be seen as complementary instead than alternative and to support this, it makes use of the System Dynamics. The choice of this methodology is due to the possibility to represent loops and feedbacks, things which are hard to deal with the traditional economic modelling tools; this advantage, in this work, more than compensates the disadvantage of the lack of maximisation in some behaviours. With the System Dynamics[1] a complex representation of a local economic system can be drawn and a simulation model consistent with the representation built and simulated. The model encompasses most of the features of the 'heterodox' theories without encountering any contradiction among them but, instead, with the support of issues of more than one theory in each block, therefore corroborating the argument of their complementarity.

In addition to this, the paper shows that the outcome of different levels of development and agglomeration among similar territories may be possible also starting from an heterodox framework. In fact, when dynamic returns are allowed, and in particular when the competition is based technology, which is produced through a cumulative process, the competitive advantage tend to reproduce itself and multiple equilibria are allowed in which the regions persist at different levels of competitiveness. The advantage of this approach is that the model can also be randomly simulated; in this way the model is able to represents a stickiness of the ranking of the regions, but without any deterministic ever lasting outcome; it produces therefore an output which is more realistic than the one of the traditional models.

Summary

A simulation model of a local production system, compatible with all of these theories, is built as extensively explained in section two. The focus is on the capability (or non capability) of the system to engender the right virtuous circles, which allow it to continuously innovate and, in this way, to be competitive.

Examples of simulations are in section three; they show, on the one side, the ample possibility for the model to implement and simulate the effects of a large number of regional policies and, on the other side, they reveal the advantage of structural policies on transfers of resources when the purpose is to generate long lasting development.

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[1] In particular we used the simulation software Stella, in its version 5.1.1 and all diagrams and graphs come from this software.

Section four demonstrates that, with a model like this, it is possible to produce different levels of development in different spaces: a number of models identical to the one of section two may be appended the one besides the other and linked through technology. It is in this way illustrated that different but structurally equal regional systems may persist at different relative technological levels; consequently they are differently competitive and, therefore, at different welfare levels, this due to the cumulative nature of knowledge. This outcome, which will be called 'agglomeration', is more similar to what we observe in the advanced world than agglomeration through the movement of people or firms that we can read of in many models. In fact in Europe, at least, what we observe is not a huge agglomeration of production factors, but different levels of competitiveness and richness depending on the learning/technological ability of territories and on the subsequent level of the functions they accomplish.

Section four concludes with the achievements and the limits of the model and the policy recommendation that can be drawn from this exercise.

Section Two

The model

When writing the model, a number of general features were used throughout. Not all the possible relevant endogenous variables were included; this first to avoid the "verisimilitude trap" (Gilbert and Doran, 1994) that consists in adding too many details not because needed but simply because plausible, second because the focus is on the development of the two virtuous circles in which we will go more deeply below. Because parsimony is a quality in a model, the number of exogenous variables has been limited too, because there are decreasing returns, in terms of realism, of the number of parameters.

A precious characteristic of the model, allowed by the methodology of the system dynamics, is the interrelation: each sector is linked with all the others[2] (see Fig.0), and this is important since we wanted to focus on the analysis of a territorial production and innovation system and not on its single components.

A few general procedures have been used when entering the equations: most of stock nodes have a dissipative mechanism, justified by mechanisms of deterioration and obsolescence, or by the normal turnover (through births and retirements) of the population; the environment is the only node that has a conservative mechanism which is justified by the possibility of nature to regenerate itself, even if in the long run. The local technology node is not dissipative, but must confront itself with a continually growing external technology, so that it also has to be supplied at all periods

Throughout the model, the single equations have decreasing returns to scale, as it is plausible to be in the real world, but the interaction of all give rise to dynamic increasing returns to scale so that the model has a central instable equilibrium (in which it was calibrated and with all possible nodes equal to 1, by assumption) and two stable, one upper and one lower, equilibria.

[2] Even if, in the Stella representations, a large use of "ghosts" has been made: this tool allows to replicate the symbol of a variable elsewhere, in order to reduce the length of the arrows and therefore increase the easiness of reading.

Whenever possible the equations are in multiplicative form so that the elasticity of a variable to another can be set up easily. Concerning these elasticities, once decided that the returns are statically decreasing and dynamically increasing, the choice is not very important in a theoretical exercise. In fact, the elasticity parameters can be significantly changed without qualitatively altering the functioning of the model; moreover, the elasticities actually used in the simulations are chosen intermediate, so that, even if it is possible for many researchers to disagree on them, it should be impossible to find a general consensus on the direction of the possible modification.

The virtuous circles that feed the competitiveness, in the model, are the following: first (Fig.1) there is the more traditional circle of the accumulation of local resources (infrastructures, services, etc.), these have a positive effect on competitiveness, thanks to the achieved competitiveness a monetary output can be produced and part of this can be reinvested into the accumulation of local resources. The second circle (Fig.2) is less traditional and is the one of innovation: by innovating, the system is able to continuously generate technology and in this way of being competitive; competitiveness generates value added which can be reinvested in learning and R&D, and hence allows to continue the innovative process.

There are therefore four main blocks in the model, corresponding to the 4 main components of a local production system: (1) the local government, which drains resources from the territory and can use these to build infrastructure and services necessary to make the territory competitive; (2) the firms, the agent belonging to the territory[3] that produce value added by using the inputs available, moreover the firms can reinvest part of the profit in innovation and human capital, and create networks; (3) the workers, that strictly linked to their territory, who are important because the learning mechanisms are embedded in the people living in the places; (4) the innovation dynamics, both the creation of new technology or the imitation and diffusion of existing one, that is fundamental for the competitiveness in a region belonging to the advanced world.

Each sector will in turn be illustrated in the following pages.

This schema has its predecessors in the work of Freeman (1987) who, in its analysis of Japan, indicated in the central government (since its analysis was at the state level), in the education system and of professional qualification, in the R&D strategies and in the relationships among firms and between these and the central government the key sectors to investigate.

More recently Bramanti (1999) designated as the four focal points of the emerging paradigm of the relational development and of territorial competition the innovative processes, the network relations, the learning mechanisms and the governance mechanisms.

Nevertheless, when modelling, there was complete freedom of movement between theories and authors, even if remaining inside the four blocks framework (Fig.3).

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[3] In this work it is assumed that the firms are not supra-national bodies seeking for the best location, but are generated in the territory by the people of the territory and therefore are strictly embedded to it, a thing that is common to many industrial spaces in the advanced world.

Learning and human capital

The learning mechanisms are represented in two of the sectors of the model. In fact in the literature there is a clear distinction between information and knowledge, with the first belonging to all which can be blueprinted and the second that, together with active understanding "[...] resides in the heads of individuals" (Simmie, 1997, p.7). The modelling of information is in the innovation block, whereas the knowledge is in the learning one, which, with the use of a population dynamics, embodies the fact that "in each technology there are elements which cannot be written down in blueprint form or are difficult to verbalize and can therefore not be diffused easily" (Carlsson and Jacobson 1997).

The tacit knowledge (basically but not only know-how), is incorporated in the people, for this reason this is the sector with the largest inertia.

In the old economics labour is a production factor as the capital, and its productivity is determined by the technology and the amount of capital per head. In these analysis economic growth can be determined by the growth of population. On the contrary, in the modern economies, the demographic pulse has arrested and the global competition is not only on the cost of production factors but on that complex set of factors that stimulate and generate permanently the innovation (Maillat and Kebir, 1998).

The name of the block is due to the fact that it includes the two different learning processes well described by Goody (1998, p.174): "We may look at the diffusion of knowledge in terms of two processes, the intergenerational and the intragenerational. The first involves the communication of information from adults to children, either in the largely domestic environment of oral cultures or in a largely external setting, as with the schools of literate cultures. […] The second axis of diffusion is between adults and is concerned partly with the acquisition of existing knowledge, partly with its creation and partly with the transfer of information in the course of daily life."

In the model, therefore, there are three stocks of workers:

The unskilled, workers without any particular ability who in the model constitute a residual class and are not a factor of competitiveness.

The skilled, workers that, holding or not a formal qualification, have the skills needed for the job they are doing. The presence of a larger quota of skilled workers in the system has its positive effects on the costs of the firms (Wiig e Wood, 1997), but also on the easiness of imitation of external technologies.

Beyond the no growth of population, there is the further assumption that both these groups of workers are not mobile outside the local system. This fits very well the European case where workers are rarely mobile internationally, nor inter-regionally.

Finally, there is a separate stock of workers, these mobile not only nationally but also internationally: the R&D personnel, called as in the Research and Development Annual Statistics of Eurostat. These constitute usually less than 2% of the total population and are not only mobile but also usually concentrated in the capital cities areas or in specific advanced regions. The factors that are assumed to affect the location of these are not only the level of instruction infrastructure in the region but also the level of Research and University, the specific investments done by the firms to attract them and also the level of amenities in the territory, to which they also appear to be sensitive. The R&D

personnel has a retirement system and is modelled apart of the two other stocks of workers which, on the contrary, are strictly linked.

In fact the total number of skilled and unskilled workers is fixed and normalised to 1, with a retirement mechanism that in each period substitute workers with new entrants, whose skilled % is determined by the level of instruction in the system. During their working age the skilled workers can become inapt to their duties because they do not automatically follow the evolution of the modes of production and therefore become unskilled; this obsolescence mechanism can be contrasted by a training mechanism, which is either public, through instruction, or financed by the firms.

Innovation

The dynamics of explicit knowledge is drawn in the innovation block.

This is the real engine of growth and competitiveness of all the system, where internal factors and interactions with the external environment determine the positioning of the region with respect to the technological frontier.

The importance of innovation for growth was known long ago, but before the 80s its mechanics was still rarely esplicitated and seen rather as a “black box” (Aghion and Tirole, 1998) of which both the inputs and the outputs were known but not the inside functioning. The part of growth not explained by the accumulation of physical or human capital and therefore due to technological progress, constituted the so-called “residual” (Solow, 1957).

With the re-discovery of Shumpeter, the evolutionary theories and a new focus on innovation in mainstream economic growth theory, as in many endogenous growth models, the innovative process is now central to any economic growth investigation. Moreover in many theories, as rapidly mentioned in the introduction, innovation is a local (in a scale that is sub-national but not too small) process.

In this model, coherently with the heterodox theories outlined in the introduction, technological knowledge is shared among all the actors of the territorial system, and the innovative process is the outcome of a collective effort of which all firms can benefit.

This fits very well to the ‘innovative milieu’ case, where knowledge is in large part shared, but also fits the learning regions and all these cases of local systems of production (that are prevailing today in the developed world) in which technology is vital for competitiveness and the level of overall technology is at the basis of the performance of the system taken as a whole.

In the Shumpeterian tradition the innovation concept is wide enough to encompass (a) the introduction of a new good or a new quality of an existing one (b) the introduction of a new production method (c) the opening of a new market (d) the acquisition of a new source of inputs (e) the introduction of new organisational forms in an industry (Antonelli and De Liso, 1997); according to Cooke, Uranga and Extebarria (1998), Shumpeterian innovation accounts for 80-90% of the productivity growth that is estimated to be more than 80% of the GDP growth of the industrialised countries.

For modelling purposes, the shorter definition of Edquist and Johnson (1997, p.42) according to whom "technological innovations are […] regarded as the introduction into the economy of new knowledge or new combinations of existing knowledge" is best suitable.

The characteristics of technical development which are by a large agreement thought to be independent of specific context are (Teece, 1998): *uncertainty*, so that the modelling has to involve stochastic variables; *path dependency*, due to the difficulty of escaping from technological trajectories; *cumulative nature*, because most of what is found is built on what already existed and moreover draws on tacit knowledge; *irreversibility*, not only because of the large investments that new technologies often need, but also because of market failure as the lock-in that makes difficult to change a standard with a superior one once it is widely diffused; the presence of *interrelation* between sub-systems, with other users and developers, necessary for the success of an innovation; a large degree of *tacitness*, i.e. knowledge impossible to codify and therefore difficult to transmit; a certain degree of *appropriability*, which has influence on the propensity of the economic agents to invest in innovation so that there is often a trade-off between the static efficiency, that would claim for as less as possible appropriability to increase welfare and the dynamic efficiency that is due to the stimulus to innovate coming from the possibility to retain the profits.

What role for the territory in this process? In the words of Porter and Solvell (1998, p.446), it is "central to the question of how easily knowledge embedded in one local cluster can be imitated by outside actors. If diffusion is indeed rapid and can be accomplished at low cost, globalisation forces would override earlier locally confined innovation. If, on the other hand, diffusion effect is sluggish, costly and involves long lead times, then localised innovation processes will remain essential". The model allows both cases to be simulated, since it is endowed with a intentional local innovation, a costly imitation and a free diffusion mechanisms, whose parameters can be adjusted according to the opinions of the user.

The case that is more interesting, however, is the one of sluggish diffusion that allows for the space an extended role in which (Bramanti and Maggioni, 1997) there is co-ordination of industrial decisions, the political choices on localisation, creation and repartition of resources are taken, there is the formation and evolution of untraded interdependencies and actors learn technologically and organisationally, technology and innovation are created generating a process of collective building of resources.

In building the model, the suggestions of Nelson and Rosenberg (1998) were followed where possible: first they suggest to consider the technological investment in large part as product of investment intentionally decided and directed toward it; second, parsimony does not allow to exclude a role for public and not proprietary research as that in universities and public R&D institutions; third unavoidable point is the inclusion of uncertainty, different from risk because it is not calculable in advance.

In addition to these features, innovation has been considered, for the reasons explained before, a process radically embedded into the territory.

For this reason the innovation block is built on the interaction of two stocks of knowledge (called local and world technology) with the influence of the stock of R&D institutions in the territory).

The mechanism best suitable to the evolution of world technology is an exponential one, in which at each simulation period the stock of world knowledge grows of a percentage p, so that the cumulative nature is taken into account. The parameter can be kept fixed in the simulations for simplicity reasons but is assumed to be stochastic so that technology can be submitted to unpredictable cycles and shocks. The local stock of knowledge also grows at each simulation period, but under the composite effect of three forces: a spontaneous and not costly diffusion[4] and a costly imitation take part of the technology available in the world but not locally and copy it into the territory; the third is the local capability to innovate that is built cumulatively on the local stock of knowledge again with a stochastic exponential parameter, but now this parameter depends on the endowments of the system itself.

The interaction of local and world knowledge creates an index of technology gap that is at the basis of the competitiveness of the local system since the focus is on relative competitiveness.

A number of exogenous parameters and endogenous stocks influence these three mechanisms: diffusion is influenced by the openness of the system and the presence of a skilled workforce; imitation by the previous two plus the spending of firms (in particular those of the ring sector that don't spend on own innovation); innovation is determined by the stock of Research and University institutions of the system, with this stock being affected by obsolescence as all infrastructure but more rapid and with input coming from public spending, firm investment and R&D personnel presence.

When the local system approaches the technological frontier, an increasing part of the knowledge produced locally can be thought to be completely new worldwide, so that its effect is to increase the stock of world knowledge as long as the local one. This mechanism adds realism and avoids the explosion of the system, but is also the reason because the model is suitable to explain relative growth (competitiveness) instead than absolute one.

The model was calibrated in an equilibrium in which the summed effect of the three inflows of local knowledge gives the same rate of growth of the world knowledge so that the both stocks grow exponentially but the gap is stable; in simulations the system has the possibility to start virtuous circles and reduce the technological gap but also to start vicious circles and lose ground; this will be more extensively discussed in section 3.

Market and enterprises (networking)

The core of any local production system is constituted of a web of firms that can represent a positive factor for the development of the territory but, if this web is less dynamic and diffused, the lack of entrepreneurship can be a constraint on local development that is hard to overcome in the short run, even with the most appropriate policy.

The block of the model which includes the market, the firms and their relations is called networking. The assumption of the model, coherent with the reference theory, is that production is a local process for which the firms use extensively immaterial resources (like knowledge and skills) that are at a sub-national level. The market, instead, is external, so that the demand for the firms of the region is more dependent on the

[4] We think that no knowledge can be kept forever and that it would naturally, even if not fast, flow from the more advanced places to the less advanced simply through communication or commerce.

national and international demand more than to that of the region itself, even if both effects are included in the model.

In literature there are many possible classifications for the firms (according to age, size, property, etc.) but the most interesting classification, when dealing with the innovation capabilities of the local production systems of the advanced economies, is the one between core and ring firms. The classification used here is similar but not coinciding to the one used by Storper and Harrison (1991) in their taxonomy of the governance mechanisms in the local production systems, (all core, all ring no core, core-ring with lead firm, ... core ring with coordinating firm) and probably more similar to that between “leader” and “indotto” of Folloni and Maggioni (1994). The firms here indicated as “core” are those that compete on the markets with their dynamical ability to propose innovative products; the firms of the “ring” are not only the furnishers of the first group but, more extensively, all firms that renounce to compete with always new products and locate themselves in the manufacture of more mature products. The behaviour of the two groups of firms, as was already previewed when illustrating the innovation block, is differently modelled.

An assumption allows to represent the firms as continuous variables: since all the establishments of the different sectors are in general of different size, the total of the production capability is not made of a number of quantums of equal size, but can be treated as if it was the “quantity of firm” of the local system; to see it differently, it could be a proxy for the “entrepreneurship” available in the system, once it is assumed that this has a direct relation with the amount of entrepreneurial initiatives in the region.

The amount of core and ring firms can change, but not as much as other variables, and this is realistic because, coherently with the ‘heterodox’ theories, we consider the firms generated by the people living in the region and, therefore, it is not plausible that the production capability of a single place can grow more than a certain amount (apart, of course, the productivity growth due to technological advancements, that is modelled differently).

The cost function for the productive plants is also unique for each group; this does not need to assume that all firms face the same costs, only that the overall average effect can be modelled. And the costs of a plant are very dependent on the endowments of the region of location (Porter, 1994).

The variables that are thought to have influence on the production costs are similar for the two groups but not coincident: both have the quantity of infrastructures per firm, the quota of the skilled workforce and the technology gap (with a lower parameter for the ring firms); the core firms’ costs are also influenced by the presence of R&D personnel and, positively, of ring firms in the territory: some of them can be sub-contractors.

There is a mechanism of mobility of firms, limited to model only the net effect of mobility, that depends on profits, the openness of the system, the interaction between the two groups of firms (so that the core firms take advantage from the presence of ring firms and vice versa) and the congestion/concurrence effects (so that both the core and the ring firms are hampered by the excessive number of firms of the same type), and on the reproducibility (a synthetic indicator of the endowments of the territorial system that will be discussed later on). This net mobility allows a number of interesting policy experiments as the introduction of a large plant financed by the central government that has usually positive effects in the long run but that in the short run crowds out the existing local firms.

The market mechanism, not central in this paper, has been chosen as simple as possible: a demand function with constant elasticity of price, chosen in a way that the tax rate influences the profits but not the gross mark-up and the prices of the firms. The demand function is influenced by variables and parameters: among the latter the openness of the system which has negative effect on the ring and reversed U effect for the core; the technology gap has an important effect (negative for both types of firms), since products with more technological content are either more demanded or less sensible to price than other less advanced (Campisi, La Bella, Mancuso, Nastasi, 1997); the level of services provided by the public administration is important and positive because of their role in the model of increasing the capacity to penetrate the market (Onida et al., 1992); the concurrence between firms of the same type has negative effects for both types, but the quantity of core firms has indeed a positive effect on the quantities demanded to the ring (since a part of their supply is provided locally).

An independent simulation variable (market cycles) is added to allow the simulation of shocks and cycles which may affect the local system.

The profits of the firms, calculated as multiplication between the difference of unitary prices and costs per the amount of firms, constitute the value added of the system that is the major output of the networking block. This value added is in part levied up by the public administration by the mean of taxes, in part constitute net profits (that are supposed to go to the local inhabitants and so are a welfare indicator), in part is reinvested by the firms in innovation and in human resources in the way that was described when analysing the previous blocks.

The quotas, in which the profits are divided, as long as the taxes, are important parameters that can be changed to simulate policies and reactions.

The role of local government

The fourth block of the model is called government and includes all the variables that are controlled by the local government and other organisational variables that are not in the networking block.

The fundamental role for this block is the allocation of public spending among the different needs of the territory. The local government gets resources from taxes, borrowing or the central government and spend these resources through the vectorial "expenditure" variable. According to Cooke, Uranga and Extebarria (1998) there are three main systems in the creation and use of public resources locally: the case of *decentralised spending*, in which the central government takes the decisions that are afterwards implemented by the local authorities for efficiency reasons; the possibility of *autonomous spending*, when the local government has the rights to decide how to allocate the resources which still come from the centre; the presence of *taxation authority*, when the local governments can also levy the amount they chose of taxes. The model can simulate all the three cases, but it is the third that is more interesting since it allows to better distinguish the effects of the local policies and because it is what many local authorities aim to today.

There is no absolute best scale for local economic policies, it depends on the efficient scale for decisions and implementations; however it is important to remark that the services that are more important for the firms are those available locally because of their accessibility.

Lundvall and Johnson (1994) assert that the market mechanisms works well enough in the allocation of existing knowledge, but that in the learning economy (as that of this model and of the advanced world now) the mechanisms of learning and of innovation are also fundamental so that the intervention of government is necessary according in five aspects: (a) it can provide the means of learning, i.e. increase the capability of learn and innovate through investment in education and training; (b) it can give incentives to learn, with a policy apt to encourage innovation; (c) it can increase the capability to learn, using policies apt to favour the organisational change inside the firms; (d) it can promote the access to the relevant knowledge not only with high-level academic institutions but stimulating the transfer of knowledge and the co-operation between these and the firms, especially those in the high tech; (e) it has also to create the premises that allow the agent to learn to forget , that is to abandon all these skills that are obsolete.

In the evolutionary literature, therefore, we observe that support to innovation and creation of new resources are added to the traditional government task of optimal allocation (Belussi, 1997).

The government of this model performs all these roles: through the vectorial variable expenditure it provides local services to the firms, it invests in education and in R&D, it heals the environment and provides infrastructure. The last two, never mentioned before, have to be described.

There is a stock called "environment" in the model that represents the level of physical amenities that are present in the system. It has a starting level and it is structured so that it deteriorates under the burden of economic activity and of population; it can be improved with public expenditure (we assume for simplicity that no private agent would do so) and has a mechanism of bio-persistence that makes nature tend to get his standard level in the long run.

Infrastructure, the third stock under direct government control, is the nucleus of the Social Overhead Capital, and its importance has been at the centre of an intense debate following the works of Aschauer (1988). Here infrastructure is indivisible, non-proprietary and generic, but not a public good strictu sensu since the number of firms that use it matter. Infrastructure in the model is different from "services" because in the infrastructure node are included all the public structures that need a certain amount of time between the expenditure and the operative result. Infrastructure, as all the features of the systems, is subject to wear off and obsolescence.

A number of parameters are included in the sector, as the level of adequacy of the government (represented as the amount of expenditure that really goes to its duties), of corruption, of associationism. Moreover there is the possibility for the local government to get extra-resources from the central government or to borrow at a settable interest rate; these features allow the simulation of a number of policy experiments.

A suitable synthetic Indicator

The simple per capita value added indicator, even if very important, appears insufficient by itself as final indicator of a complex system as this one. This because it is static, and therefore you can have a high level of value added in a period simply because of a favourable temporary shock when the system overall is badly working and in this way losing ground with respect to the competitor localities.

In addition to this, the role of environment as an indicator of quality of life can not be neglected; for these two reasons the final synthetic indicator of this model is built ad-hoc to include static as well as dynamic factors, economic as well as environmental variables

If two of the parts of this indicator are undisputedly the net profits per capita (that is the part of value added that is then spent by the citizens) and the environment level, the dynamic indicator has to be discussed. It should capture the "sustainable advantage" of the system, that is its ability to produce and reproduce in time the factors of economic performance, that is, to use Florida (1995, p.535) words, of "re-creating, maintaining and sustaining the conditions to be world class performers through continuous improvement of technology, continuous development of human resources, the use of clean production technology, elimination of waste, and a commitment to continuous environmental improvement".

A solid productive fabric can be an insurance for the future since for example (McCann, 1995), a place with a solid fabric of infrastructures and skilled workers, due to the presence of a district of firms in a sector, can experience a crisis due to the crisis of the sector; but, after a few years, the same place could experience fast re-growth of its industrial activity due to the arrival of firms in different sectors which benefit not of the externalities they create but of the skills of the workforce that had been created by the previous activity.

The variable that represents this has to take into account all the factors of the model that will affect its future performance and that are, at least to a certain extent, persistent over time: the technology gap, the quota of skilled workers, the quota of R&D personnel, the Infrastructure amount, the Services amount, the Research and University amount, the Instruction amount, plus the Environment itself, for its role in capturing the mobile R&D personnel. All these are put together in a multiplicative form of the type:

$$\prod F_i^{\alpha_i}$$

Where F_i are the factors and $\sum \alpha_i = 1$

The weights of the factors are empirically[5] calculated by comparing the rapidity of the system to react to a change of them. The outcome is with a very good approximation the "resilience" of the system (Bramanti and Ratti, 1997) i.e. its capability to confront negative shocks and come back to virtuous growth paths.

Finally, the three basic components are put together in another multiplicative form as the one above to form the final indicator, but this time the exponents weights, still summing 1, are completely arbitrary: in fact they depend on the preferences, the aversion to risk and the temporal horizon of the decisor, hence on a political decision.

A first interesting conclusion that can be drawn from the model is, therefore, that no policy is the best in all cases. In fact, when running the simulations, different weights in the final indicator give different classifications of the group of policies that are compared. The advisor to the government should always try to reveal the preferences of the decision body, and then design the policy that is optimally fitted to these. See fig.4.

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[5] The software Stella research 5.1.1 does not have an automatic optimisation procedure, however a small change in these weight is not able to harm any of the conclusions of the model.

Section Three

Simulations with the model

A model, created coherently with the schema illustrated in section two, must have at least one equilibrium to be studied in its dynamic properties. Two options were available: the first one was to run the model with plausible parameters and discover towards which equilibrium it would finally converge; this would be easier but would also bear with it the limit of not being able to understand how many stable equilibria exist and the impossibility to discover possible unstable equilibria; the second option was to decide a ‘point’ and calibrate the dynamic system so that this point represent an equilibrium. All those which will be called ‘points’ in what follows for the sake of simplicity, are actually 13-dymensional vectors with the values corresponding to the 13 stocks of the model. Among all the possibilities, for the reasons which will be explored below, the point chosen to represent the calibration equilibrium was the one with most stocks with the standardised value of 1 except the skilled and unskilled workers (whose sum is 1), the R&D personnel (which has the plausible value of 0.02, i.e. around 2% of the population), and local and world technologies (whose proportion is the important value). To make this ‘central equilibrium point’ be an equilibrium, all inflows and outflows have been multiplied by appropriate constants so that each stock would persist at the same level of 1 in absence of shocks (again with the exception of technologies, which would grow forever without altering the gap).

The first advantage of this procedure consists in the fact that one could easily and immediately confront any value of the system with the benchmark of 1. The second advantage is that, given the multiplicative form of most equations, a modification of the exponents (which represent the elasticities) would not move the calibration equilibrium but only the dynamics[6].

The issue of stability of this equilibrium has to be discussed in the light of the assumptions on returns of section two. Stated of the static decreasing returns, the dynamic ones were set increasing. In fact, if the dynamic returns were also decreasing, the standardised calibration point would be a stable equilibrium; when this was the case, the model would not be widely usable since it would come back to this equilibrium after being perturbed and structural policies would only slightly move it. We would be in this way unable to show the multiplicity in the levels of development which is observed in reality. In addition to this, as shown by the heterodox theories, the dynamic returns are not decreasing and some economic spaces are able to renew their competitive advantage with time going preventing other spaces to catch up with them. When this is the case (and we believe this is by far the most interesting of the two), the calibration standardised equilibrium is unstable and an upper and one lover equilibria exist. These two stable equilibria are far enough to allow a large number of policy simulations in the interval.

As desirable, a small shock can make the system in the central unstable equilibrium start its slow path towards the upper or lower equilibrium, but the most interesting feature is that structural changes, as appropriate policy measures, can put the system more rapidly on the right growth path and also move higher and lower equilibria.

[6] Since all variables are standardised, a multiplication of the inflows and outflows of a stock by the same value only changes the speed of adjustment.

The change of the obsolescence parameters, when combined to the corresponding change in the inflows, is also able to change the speed of adjustment without changing the central unstable equilibrium.

In any case, when an economy is in a stable growth path or in a declining path (both considered as relative concepts), a shock can not change its long run trajectory (Fig.5 and Fig.6) but only structural policies (as a better balancing of government spending or a more intensive investment by the firms) can change the path. A permanent shock, affecting for example the demand, can more often than a temporary one change the trajectory of the system from positive to negative, but its magnitude has to be considerable. The introduction of cycles, on the other hand, does not affect the long run path of the system. (Fig.7 and Fig.8).

When the model is simulated stochastically, with random technology growth but on average depending on the system values, the growth paths can differ widely, and this too is a feature that we usually find in the real economies, in which it is not always clear if the system is performing some way because of the internal processes of because of the external occurrences (Fig.9), since the external situation can hide the internal capabilities.

The model can be used to simulate the effect of a large number of possible development policies, whose effects can best be seen when the simulation is run non stochastically:

Among them the installation of a large industrial plant built with national resources, that in the short run crowd out the local firms, even if it has a total positive effect in the long run Fig.10.

An increase in infrastructure exogenously financed, which has positive effects but whose impact effects are larger than than the long run when the local government has to maintain it just through local taxes (since we assumed static decreasing returns to scale it is reasonable that the doubling of infrastructure is not enough to double tax revenues) Fig.11.

An increase of resources for the local government (e.g. through state aid) which can start a positive situation but need to last to be really effective (Fig.12).

An increase in the efficiency of the use of public funds (through adequacy, for example), which has important positive effects (Fig.13)

A modification of the policy mix through the change of the expenditure quotas (Fig.14) which can have positive or negative effects depending on the fact if it goes towards a better balancing or a worse one.

A modification of the tax rate, which in general has short run negative effects on the welfare of the population but that, if well spent, can lead to more growth in the long run.

The implementation of local government borrowing, which has positive effects if done in a period in which the returns of public investment are superior to the interest rate (which is exogenous to a local production space) (fig.15).

An increase in the quota of profits that the firms decide to re-invest, which diminishes the net profits in the short run but which usually pays off in the longer run (Fig.16).

The implementation of anti-cyclical policies (Fig.17).

Title	**Figure**	**Starting situation**	**Intervention**	**Outcome**
Large plant	10	unstable equilibrium	exogenous increase in “leader”	slow increasing path
Exhogenous infrastructure	11	unstable equilibrium	non paid one period increase of investment in infrastructure	slow increasing path with immediate effect much larger than medium run
Temporary state aid	12	unstable equilibrium	one period increase of local government resources	slow increasing path with immediate effect much larger than medium run
Increase in the efficiency of local government	13	declining path	permanent increase in adequacy	slow increasing path
Modification of the mix of public expenditure	14 (comparative)	unstable equilibrium	various changes in expenditure proportions	various paths
Local government borrowing	15 (comparative)	unstable equilibrium	temporary increased expenditure followed by temporary decreased expenditure to pay the debt	positive or negative depending on the interest rate
Increase in the quota of profits re-invested by the firms	16 (comparative)	unstable equilibrium		
Anti-cyclical policies	17 (comparative)	increasing path	addition of a sinusoidal in market cycles (2) and the same cycle with the local government which borrows in recession and pays its debts in expansion	less ample cycles

Tab.1 Illustration of the policy experiments

Section Four

Agglomeration

The issue of why and when economic activity concentrates in space is widespread across various disciplines: it is at the centre of regional economics and regional science, but mainstream economics and business science are, especially after the 1980’s (Storper, 1995) experiencing a renewed interest for the question.

In order to clear up the field from misunderstandings, an old (it dates back to Hoover, 1937) and sometimes questioned classification can be useful. In the Hooverian approach the increasing returns to scale, which are supposed to be the reason for agglomeration, can be located in three different aspects: they can be internal to the firm, and in this case the economic activity will be concentrated in large plants or groups of establishment belonging to the same big firm; alternatively they can be internal to the industrial sectors: this is the case in which many firms in the same sector take profit of some common features in the locality in which they are located, for example through a labour market provided with the skills necessary to the firms of the sector thanks to the contemporary presence of other firms in the same sector. This second case is known in literature as *localisation economies*. The third possible location for increasing resides outside the industrial sector. In this last case, known as *urbanisation economies*, the firms are clustered in places not because of the intra-sectoral externalities but because their contemporary presence in a place allows to provide specific services that need a large efficient scale, such as many advanced services that, in fact, are provided only in the largest cities and that force the firms that need them to chose in which city to locate avoiding peripheral regions.

This contribution's focus is widely on the urbanisation economies, having decided not to distinguish the firms among sectors but to classify them by their attitude to innovation. The interest for the local production systems, moreover, makes the case of large integrated firms not belonging to this contribution.

The theory of comparative advantage too, should not be forgotten as, for example, Ellison and Glaeser (1997) point out that the observed patterns of location may depend on spillovers but also on natural advantage or a mix of the two and "geographic concentration by itself does not imply the existence of spillovers: natural advantage have similar effects and may be important empirically" (ibid. p.891).

In any case the agglomeration explained by comparative advantage is much more important in applied research than in theoretical contribution like this one. In fact if we give to the natural advantage of a place a large role, the model will lose its generality and its interesting feature of showing agglomeration even if different local production systems has the same functioning.

When linking externalities and clustering, it has to be remembered that in many new economic geography models the clustering of firms is due to the concurrent effect of localised increasing returns to scale (firms and labour congregate in the same place with benefits for both) and spatial distance transaction cost for which a firm may chose its location by taking into account the costs incurred in providing itself with the inputs (material or non-material) needed and the costs of shipping its products to the market. The firm therefore would choose its location in order to minimize its costs. This is not very far to the traditional Moses (1958) model, where a firm faces a triangle with the location of its two inputs and its (singular) market at the vertexes and chooses its location and the combination of productive inputs in order to maximise its profit. If the good produced remains the same when changing the combination of factors (McCann, 1994, is very critical on this aspect), the firms have sufficient mobility, the externalities and the market interaction effects are low (so that prices and demands are not significantly affected), industries with similar location of inputs and markets will tend to cluster in the most accessible places. This can be the case for, for example, some heavy industries that located very close to the ports in order to minimise the transport costs of their bulky inputs and outputs.

Positive externalities of some type are usually at the base of all models that involve effects for history accidents, as most of those of the new economic geography. In fact if the firms can take advantage from the presence of other firms, or of particular workers mobile in space or of the variety of inputs available; then positive external economies of scale arise and there is the possibility for circular cumulative processes that make a temporary accidental advantage have long term effects that cannot be reversed by an accident of opposite sign and comparable size.

The work of Marshall on English industrial districts is maybe the most known example of applied work on the causes of agglomeration. In fact he observed the spatial clustering of small and medium sized firms belonging to the same sectors and with very intense input-output relations together with external economies through the labour market, the presence of furnishers and specialised services. This theory is often cited by the economists as their eldest inspirational source and is also the progenitor of the modern theory of districts. In fact, from the observation of a number of economic realities in Italy, Denmark, Germany, but also in the US, the Fordist paradigm of an economy more and more dominated by the large (often multinational) firm able to dominate the market through the internalisation of the economies of scale, was questioned in its universality. There are in fact productive spaces able to compete in the world markets but characterised by sectorally specialised networks of small and medium enterprises (SMEs) that are linked through intense input-output and labour market relations as the original Marshallian districts. The modern studies on the districts add to these features the observation that in general there is an intense social network, which facilitates the economic relations, due to the presence of a relatively uniform cultural and social background of the actors. In many cases it is observed also a thick institutional fabric, composed of formal agencies and informal behaviours; this fabric makes easier for the economic agents to do their business by reducing the uncertainty entailed in the entrepreneurial activity; in some cases, moreover, the presence of a common background between entrepreneurs and workers makes union relations less conflictual with advantages for the competitiveness.

Probably, in any case, the most important point of advantage for the regions of advanced economies remains the presence of the relevant knowledge and the capability to renew it in time through the process of innovation (Ratti et al. 1997).

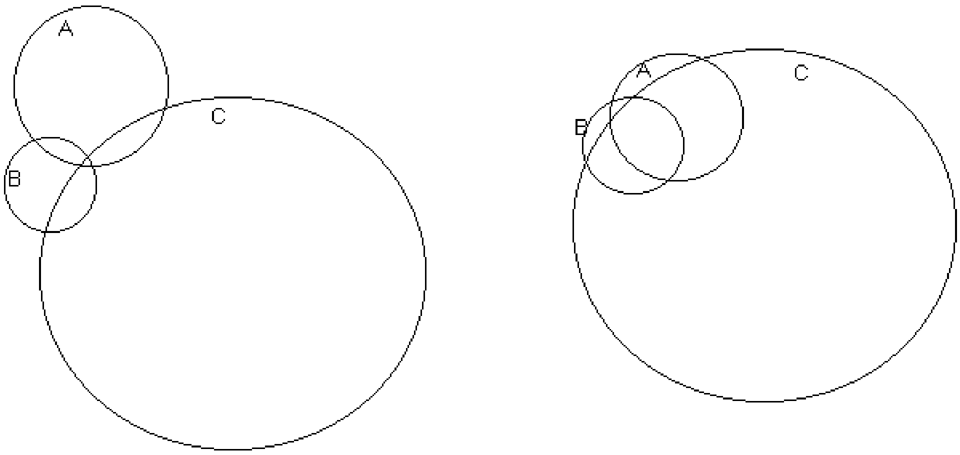
This model shows how the technological competition between local spaces of production can produce as outcome the attainment of different levels of economic development, and this despite the fact that the internal functioning of these can also be the same. The long run dynamic aggregate returns to scale in the innovative activity, can make a region get an advantage in technology that the competitors are not able to catch up.

The reason of this resides in the fact that, as pointed out in section two, the creation of knowledge is a cumulative process and therefore the followers, despite the spontaneous diffusion of knowledge and the imitation processes, may not be able to ever catch up the gap.

The model of this article lends itself to simulate behaviour like this in a simple manner: a number of identical models may be placed the one besides the other and then linked through technology.

In fact, since all the factors are assumed regional-specific and, as in occidental Europe, the workers are not mobile, the interaction between the various models (that is between the various production systems) will occur through technology. To accomplish this, the world level of technology is endogenised and becomes composed of all the technical knowledge available in all the production spaces of the model.

We assume, as we also did in section 1, that any knowledge present in a place will be part of the world knowledge, but at the same time, we allow the possibility to have some pieces of knowledge shared by two or more regions. If there exist n regions, we represent with n sets the technologies embodied in all the agents of each given territories; coherently with what stated above, we define the world technology as the union of the n sets; at the same time we also make the simplifying assumptions that first no intersection of two or more sets is empty and, second, that no set is included in the union of all the others. With these hypotheses it is possible to have representations like the two below depending on the high/low degree of subsitutability/compementarity.



The world technology is in both cases the union of the sets, no intersection is empty and the technology gap of, for example, region A, is given by the ratio between the union of the sets minus A and the union of the sets.

A simple c.e.s. type function allows to calculate the world level of technology coherently with these hypotheses:

$$WT = (\sum_i LT_i^{\delta})^{\frac{1}{\delta}}$$

Where WT is the word technology and LT_i are the local ones. The parameter δ depends on the assumed degree of complementarity/substitutability, supposed equal among the regions and has to be >1 to respect the hypotheses (in the above picture the first case corresponds to a lower δ and the second to an higher δ). The existence of multiple equilibria also depends on the size of δ, the higher it is, the more divergent the model is. In addition to this, it must not be ignored that, to be coherent with the assumptions, it is not necessary to have the same degree of complementarity of knowledge for all regions (and in reality it is probably higher for regions which are more similar and/or closer) but this realism, if implemented, would add complexity to the model without qualitatively changing the results and therefore without affecting its explicative power.

Stochastic simulations (i.e. with innovation being a random outcome dependent on the effort devoted to it) produce patterns which are different from one replication to the other and highly realistic, but which also are difficult to interpret. For this reasons the mathematical properties of the model have been analysed using the deterministic form.

For the sake of simplicity, the parameters of all the regional economies have been set so as to have, at the beginning of the simulations, all the regions in the same calibration unstable equilibrium where all stocks are equal to one (the same used with just one region); the short run elasticities were also kept equal among regions because we thought it was more interesting to confront different dynamic patterns of regions which are not different in their essence, even if these elasticities could be changed without moving the central unstable equilibrium. In fact, if different regions are simulated with different elasticities, it is like trying to explain the different performances by the mean of comparative advantage, an investigation which is more interesting in applied empirical research than in a theoretical model like this one.

The stable equilibria of the multi-regional models were searched for by simulation: starting with all the regions in the same unstable equilibrium, asymmetric (different in term of magnitude or timing) shocks put the regions on their way to stable equilibria which are reached in long run simulations (Fig.19).

With a world composed of more than one competing territory (four of them in Fig.18), there is the possibility of outcomes with different territories having different performances so that some stabilise themselves near the technological frontier (i.e. their technology is not far from encompassing all the world technology), and other in lagging positions; we observe in fact multiple equilibria, a feature which is common to most of the spatial economy literature of the ‘90s.

The novelty is that we got to this multiple equilibria agglomeration outcome in a different manner: in fact we used the c.e.s. function, but, instead of implementing a model coherent with the mainstream economics, we generated agglomeration by having at the very basis a model of economy consistent with the heterodox theories of the new regional science and innovation. It is also important to observe that agglomeration is obtained without any mobility of factors, which is instead essential to generate agglomeration in a bunch of models in the wave of Krugman (1991).

To summarise the steps followed to have this outcome, (1) we have represented the regional economy coherently with heterodox economic theories; (2) we have assumed short term decreasing returns and dynamic long term increasing returns inside every region, with all regions being identical; (3) the regions are put in competition the one with the others on technology and no factor mobility is allowed; (4) because knowledge is cumulative and helps maintain the environment propitious to innovation, it is possible to observe multiple equilibria.

If the model is simulated stochastically, its mathematical properties become less visually evident, depending on the degree of randomness, but now it is able to replicate the patterns of relative growth of the regions and illustrate the persistence of regions in their welfare ranking (Fig.20).

The policy experiments of section three can be attempted also in this extended settings, and their results, for the single region in which they are implemented, are not different in what they support: with structural policies it is easier to change the path of the regional economies than with simple injections of money. Moreover structural policies, to be effective, should target the mechanism the region use to create/generate innovation.

Limits and advantages of the approach

Before drawing conclusions it is fair to assess advantages and limits of the approach, as well as the main achievements.

The use of system dynamics allows to build a representation of the mechanics of a local production system keeping into account both the complexity and the feed-backs, two things which are difficult to represent with the standard analytical instruments of economics. Usually this difficulty leads, on the one side, mainstream economists to opt for models much simpler than reality, and, on the other side, regional scientists and geographers to often opt for descriptive models.

The approach of this contribution is instead intermediate and can represent a satisfactory compromise between the two above: it is able to deal well with both a large number of variables and interaction and allows to see the mechanisms while working in the simulations; the model is able to reproduce a large number of policy initiatives, which can in this way be understood more deeply.

The ample capability of replicating different policies and behaviours is in fact one of the most interesting features, and this compensates the fact that, differently from most economic models, not all the behaviours are optimising (it is also actually debated if, real behaviours are optimising, but this aspect goes beyond economics and regional science to psichology and is not in the core of this work).

The first limit is that this model is based on standardised values for the variables which are often (apart from the population quotas) not directly linkable to real world values; nevertheless, this feature is common to most theoretical economic models, and, moreover, since the focus here is on the mechanics inside a local system of production and innovation, it is important to see how the variables interact the one with the other more than how big, in absolute terms, are their values.

The second limit of this model is that it is not able to explain long run growth, since it has, when simulated with just one region, two stable equilibria, one upper and one lower, even if far apart; these roughly correspond to the technological forerunners regions and to the lagging ones. When the model is simulated with two or more regions, it still has a number of equilibria with one of them upper and one of them lower. We believe that this limit is not able to harm the importance of the results obtained, first of all because the stated purpose was to explain relative growth instead than absolute, and, second, since the model has to be applied to the regions of the advanced industrial world, relative disparities among these are a very important policy issue indeed. To make an example, European lagging regions are not poor in "absolute" (world) terms, nor is their population; however the gap with the most advanced justify large transfers of resources from the national states and the EU to try to achieve convergence. These regions appear now to grow on average (Canova and Boldrin, 2001) at about the same pace of the rest of the Union, but, despite this the EU still spends a considerable part of its budget (35.8% in 1999) in Cohesion and Structural Funds, which are for the largest part aiming at the development of "objective 1" regions, defined with a relative criteria (GDP per capita in PPS inferior to 75% of that of the whole Union).

Conclusions

From this paper three main conclusions can be drawn, two theoretical and one of policy.

From a theoretical point of view, the possibility to build a diagrammatic and equational representation of a territorial system of production and innovation, coherent with almost all the theories that in the introduction have been classified as heterodox, is a strong indication in the direction of an increased integration among these. In fact they appear more compatible than substitute, and the different focuses of one theory on one aspect, and of another theory on another aspect cannot make them conflict: when a methodology is able to give space to more than one aspect at the same time (as the system dynamics is), all the aspects appear to integrate very well indeed.

The other theoretical conclusion is that different levels of development and of observed agglomeration of economic activity, can have technological causes. In this model's most interesting outcome, regions can have different levels of production and also different prices for their productions depending on the level of technology embodied in them. For this reason the source of under-development or of scarce economic activity is shown to reside either in the inability of a territory to produce/imitate technology because of the malfunctioning of the internal socio-economic structure, or in the impossibility for the lagging region to catch up with the forerunners because of the cumulative nature of knowledge. We have in fact shown that when the creation of new knowledge is highly depending on previous knowledge or when knowledge is highly sticky, it may be not sufficient for the follower to have the same internal structure of the forerunner to catch up with it.

The policy conclusion is that, since more and more the competition between areas of the advanced world is on knowledge and technology, and since these are sticky and cumulative factors, radically embedded in the people living the territories, regional policies aiming at lagging regions, should not forget to target:

(a) The internal functioning of the production systems of the under-developed regions, in order to make them produce knowledge more fluidly; these policies may target the presence of human capital, both in increasing the informal qualifications of the workers (the 'skills') and the formal level of instruction also with the creation of a living and working environment able to represent a viable option for the more skilled (the only really mobile) workers when choosing where to live; the policies should also target the firms of the territory in their aptitude towards innovation and imitation, since every new investment, if the firm is not able to keep the pace of external innovation, is not by itself able to create long lasting development and may soon become obsolete; the policies should also target the public bodies, since they should be able to create an environment where innovation processes may happen, in this model the right 'mix' of public expenditure and the overall efficiency in the expenditure of funds are fundamental variables; concerning the role of infrastructure, if it has to be an effective mean of growth creation, it has to be well integrated in the knowledge creation process and, if exogenously added in quantity beyond the needs of the economy, it is not able by itself to create the economic activity which will use it.

(b) The inter-regional circulation of knowledge, so that the lagging regions could more easily acquire the technology through diffusion and imitation from the advanced ones; as we already pointed out this process is sticky and not easy to artificially produce because of tacit knowledge, the model's learning sector very well takes this into account.

The overall policy conclusion is therefore that all the available policy instruments (R&D support, education, training, business assistance, hard and soft infrastructure investment, etc. whose analysis goes beyond the purpose of this paper) should be mixed at their best in order to create a system able to compete in the knowledge economy. It is also important to notice how important is the timing of the policies.

This paper showed this in theory, but a study of the specific dynamic functioning of the system of production and of innovation of a given territory, like this did for a generic region, would allow to better target the policies and make them more effective.

This paper proved that this is worth in theory; in the real world, in order to have a more effective regional policy, it would be useful for each region to have a study of the specific dynamic functioning of its system of production and innovation, like this article did for a generic local space.

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Figures:

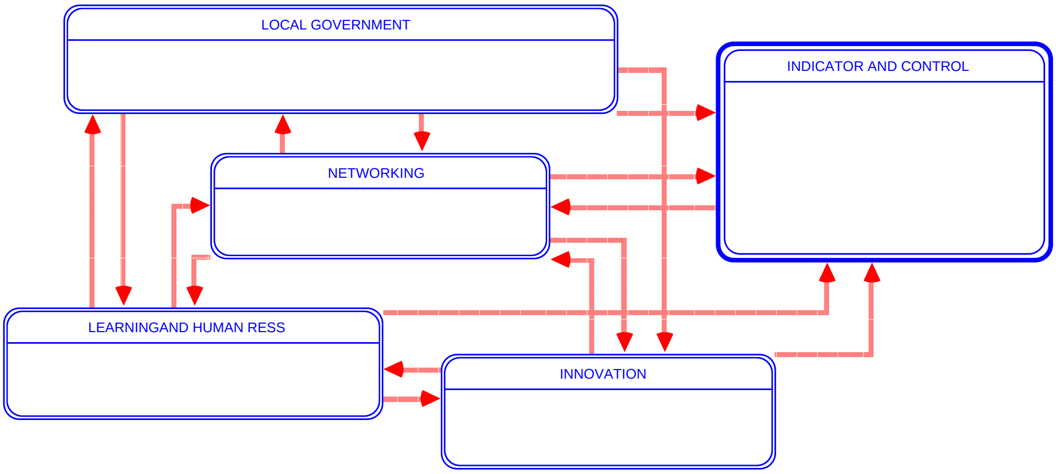


Fig.0 (the building blocks)

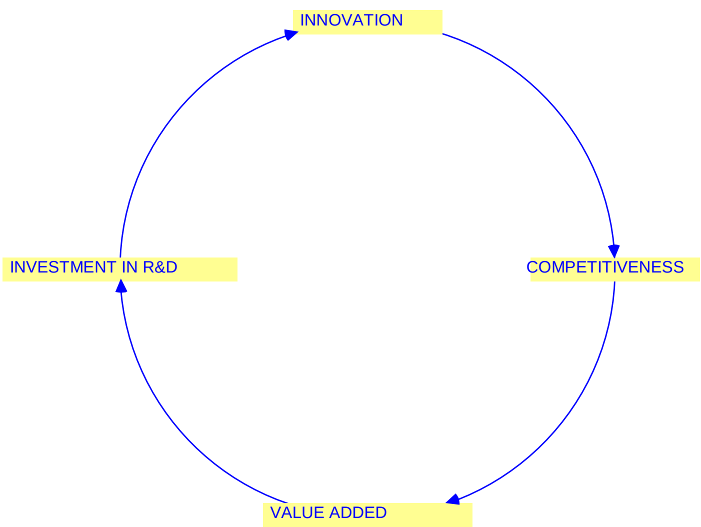


Fig.1

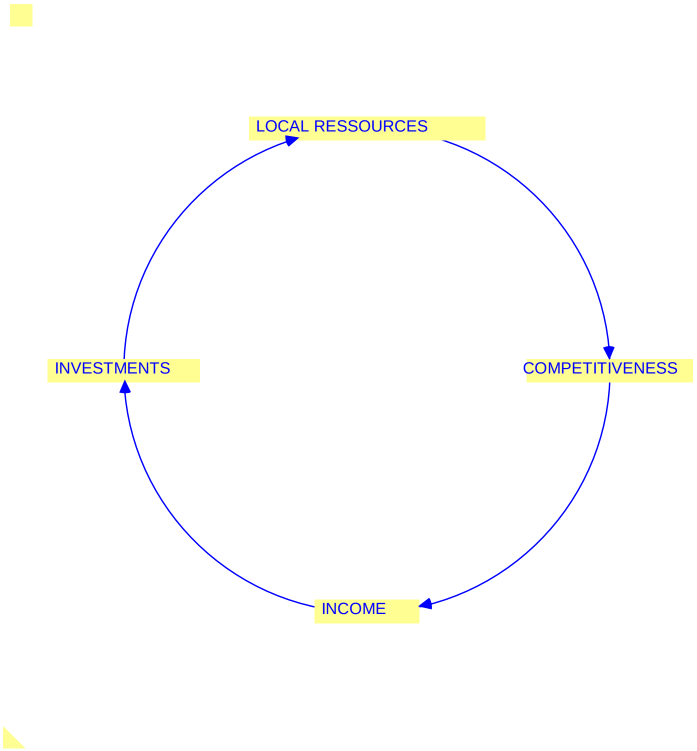


Fig.2

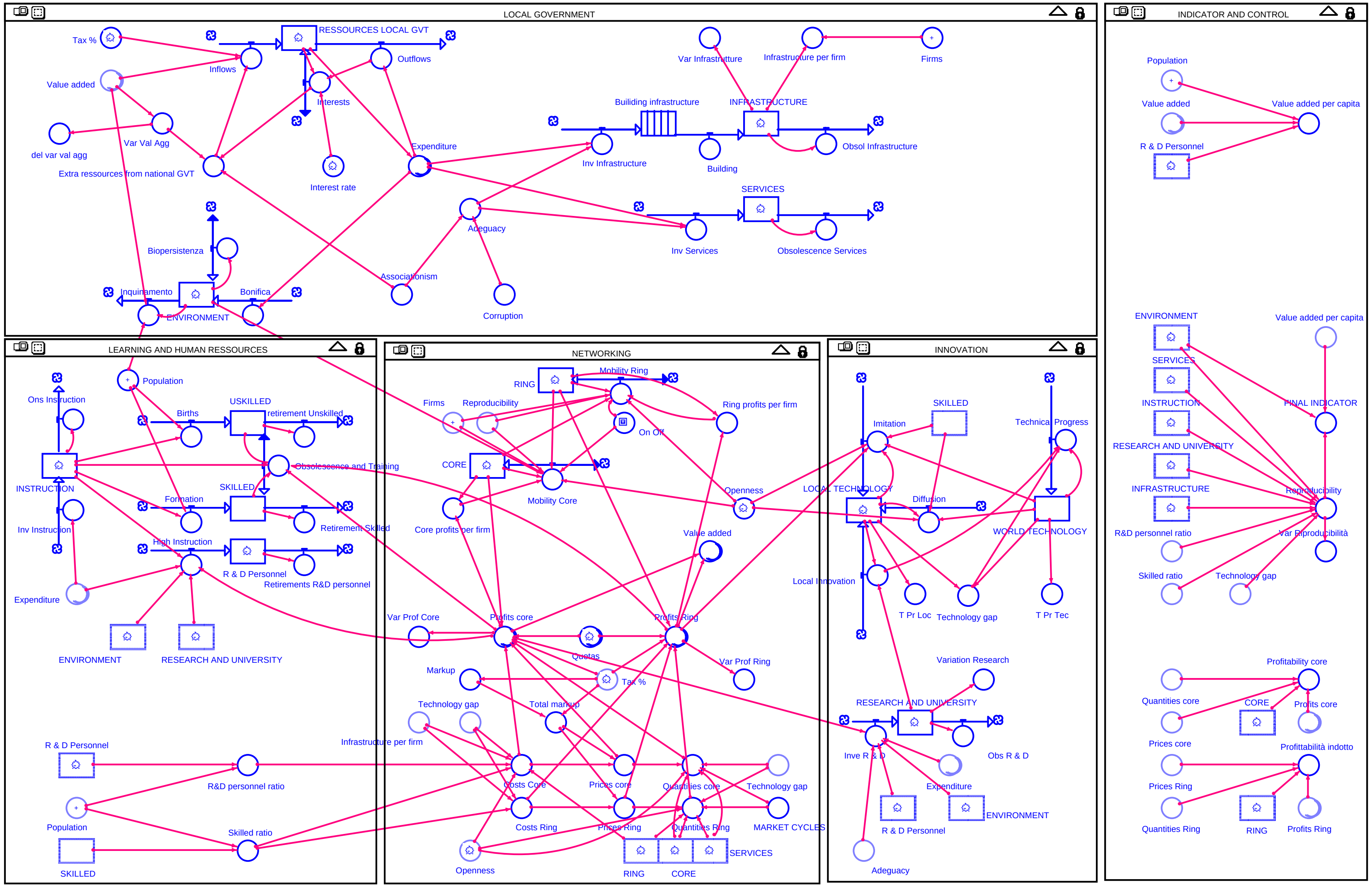


Fig.3 The model. Please notice the extensive use of the “ghost” symbol (allowing to avoid too disturbing arrows by replicating a variable elsewhere)

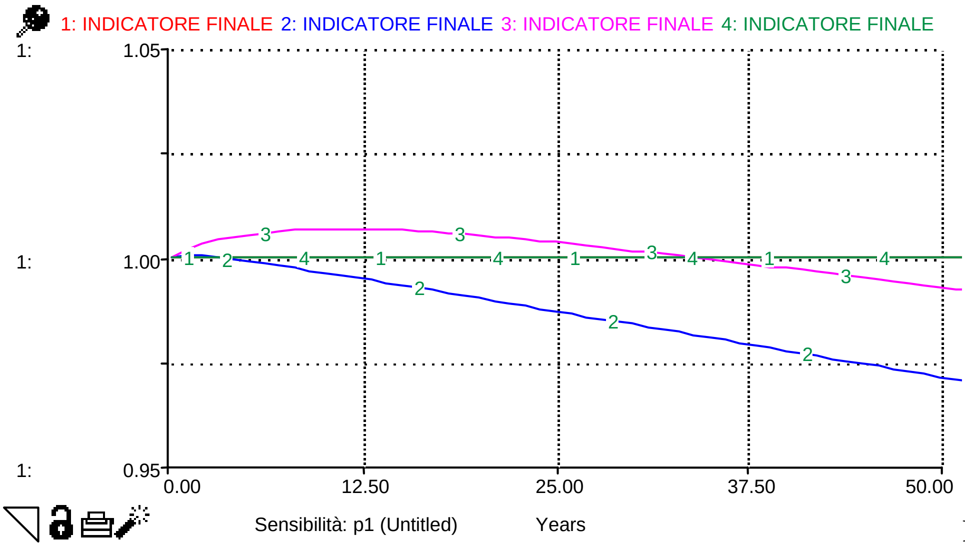

1: INDICATORE FINALE 2: INDICATORE FINALE 3: INDICATORE FINALE 4: INDICATORE FINALE
1: 1.05
1: 1.00
1: 0.95
0.00
12.50
25.00
37.50
50.00
Sensibilità: p1 (Untitled)
Years

Fig.4

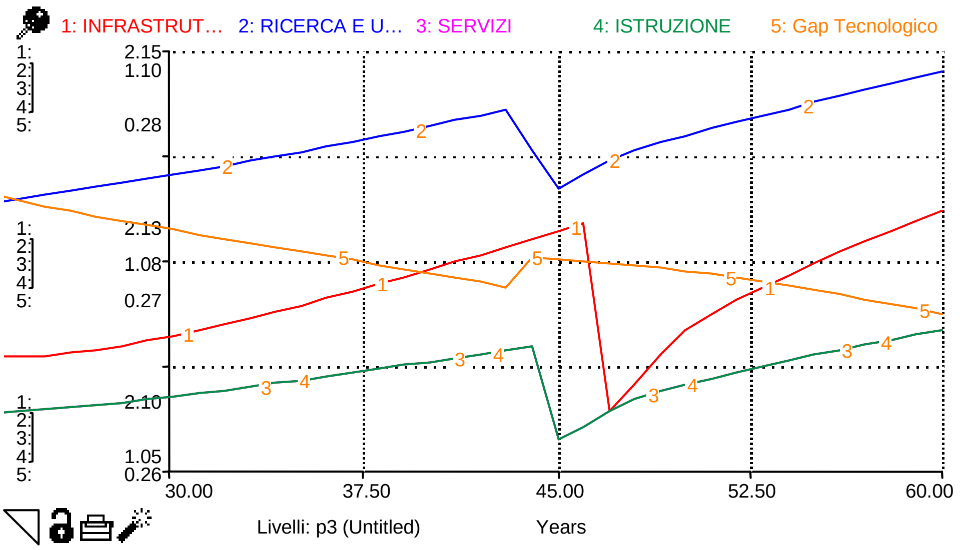

1: INFRASTRUT… 2: RICERCA E U… 3: SERVIZI 4: ISTRUZIONE 5: Gap Tecnologico
2.15
1.10
0.28
2.13
1.08
0.27
2.10
1.05
0.26
30.00
37.50
45.00
52.50
60.00
Livelli: p3 (Untitled)
Years

Fig.5

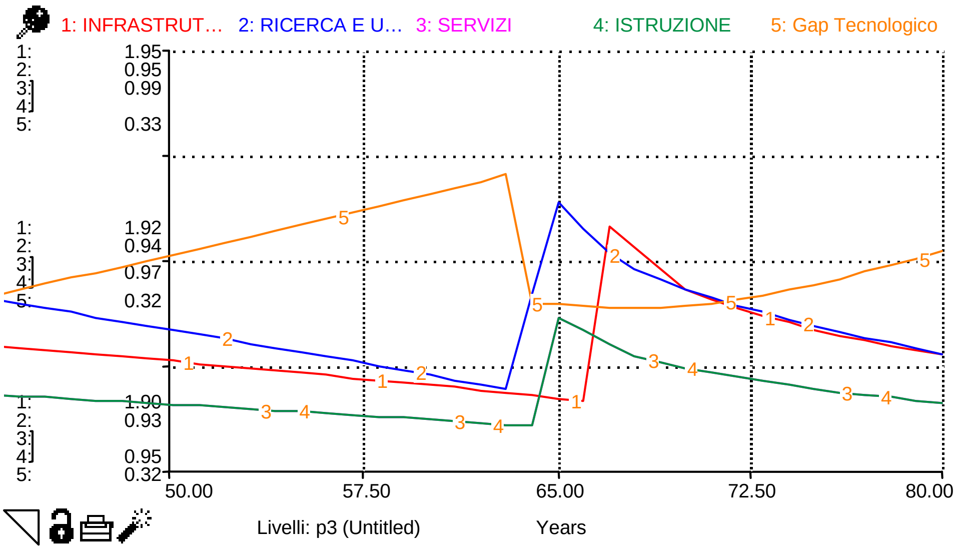


Fig.6

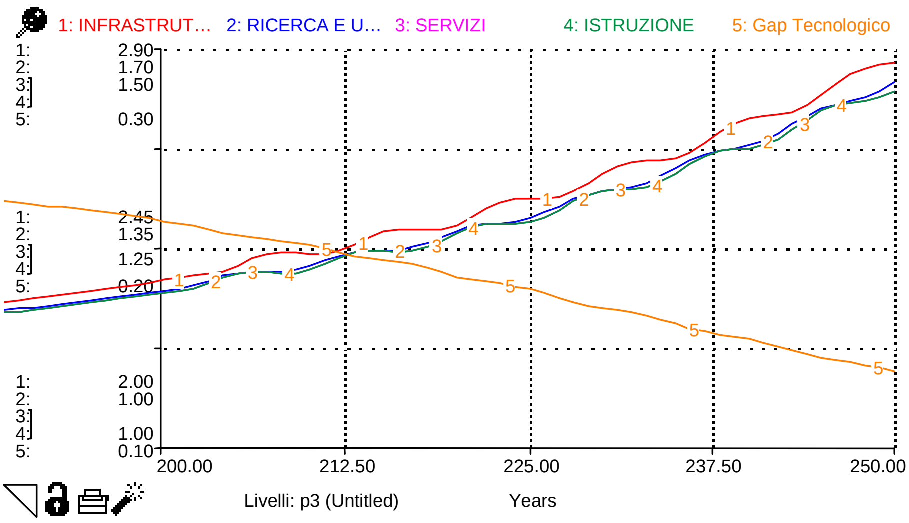


Fig.7

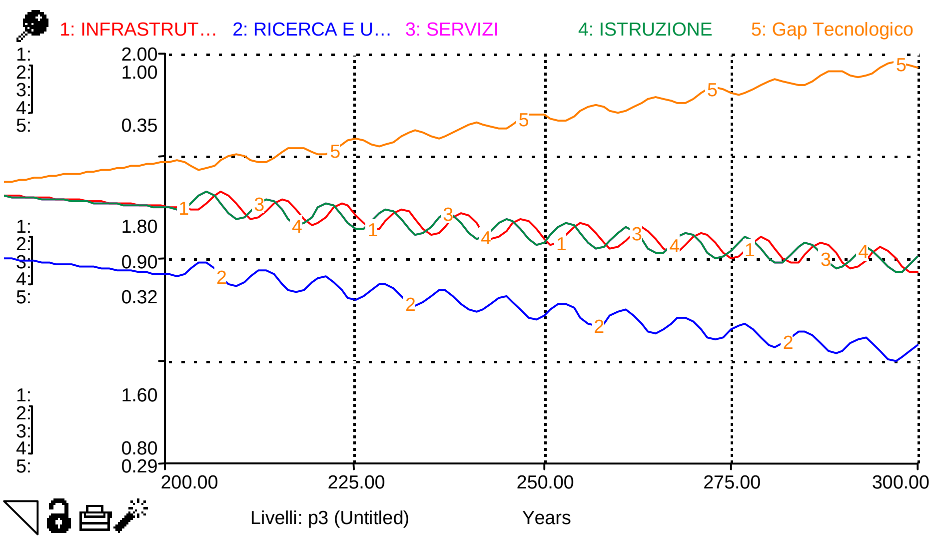
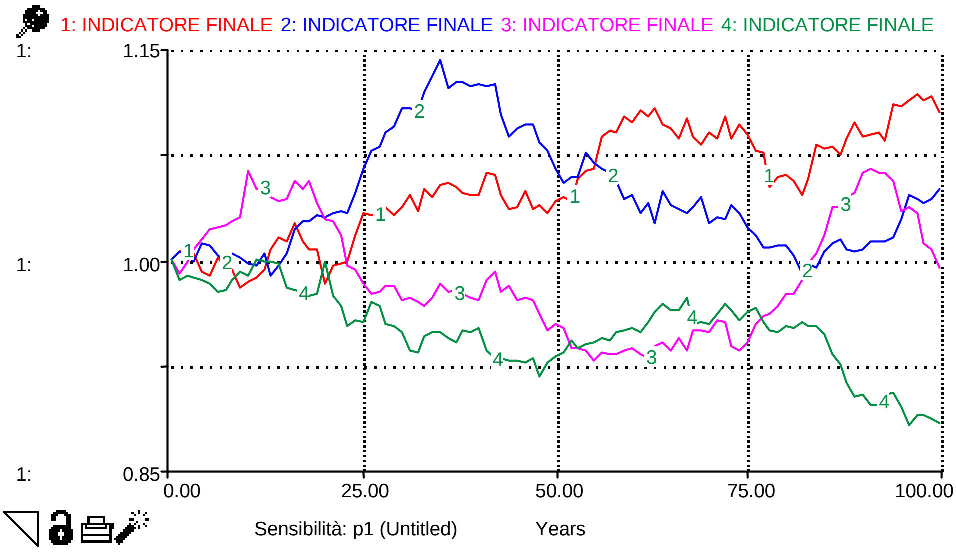


Fig.8



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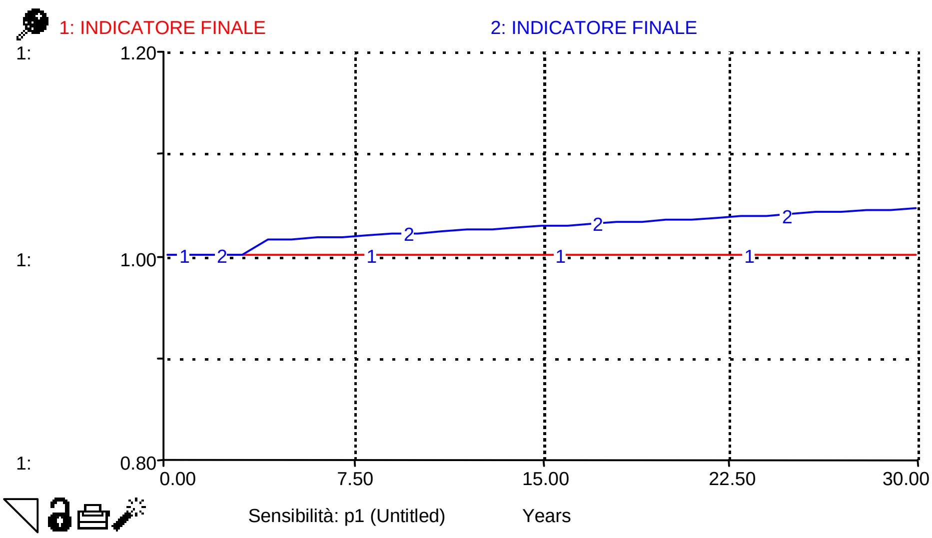

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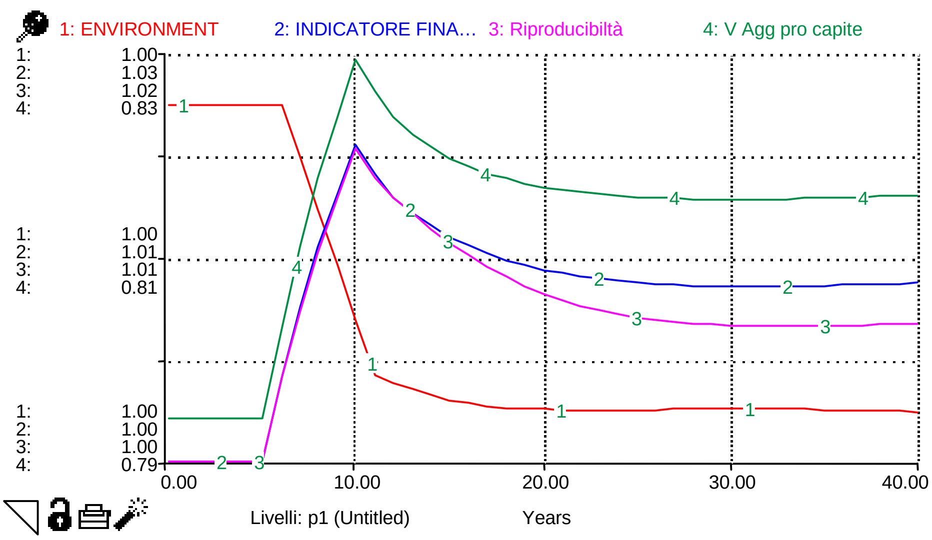
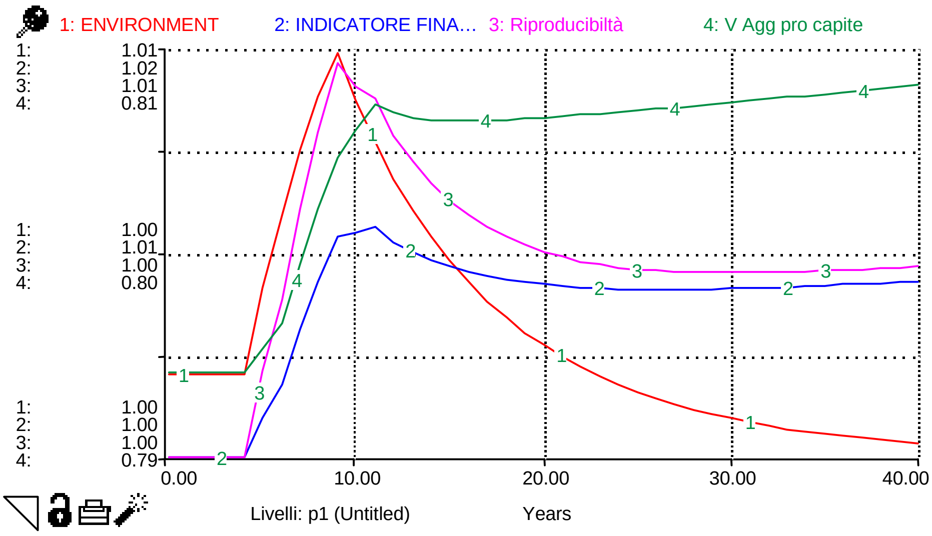


Fig.11



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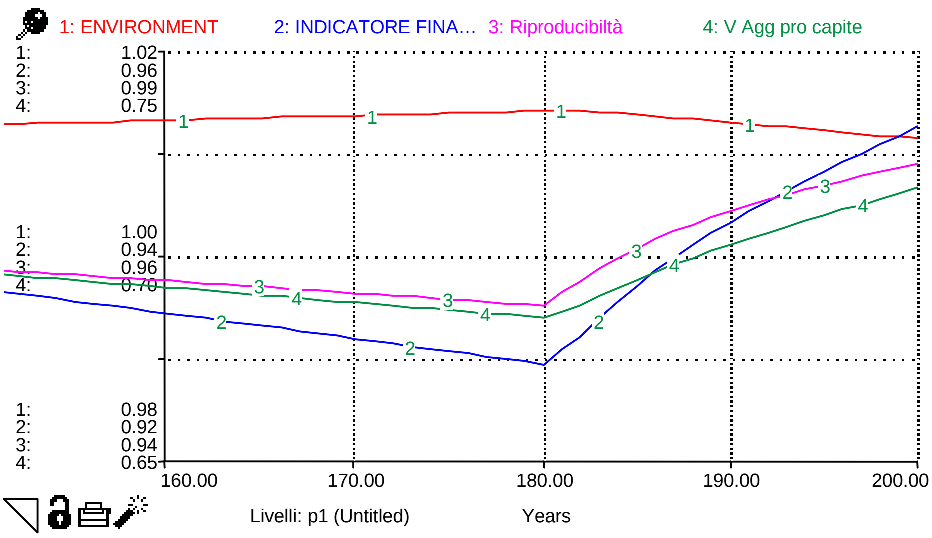

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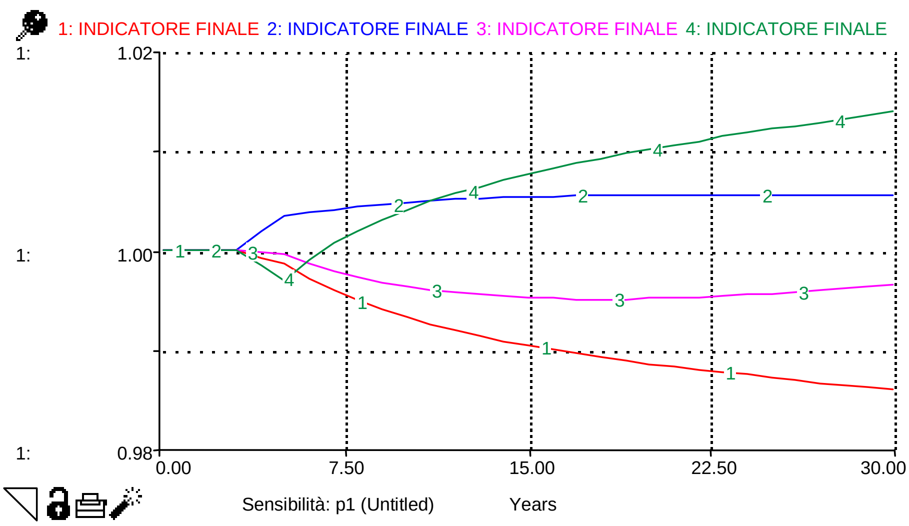
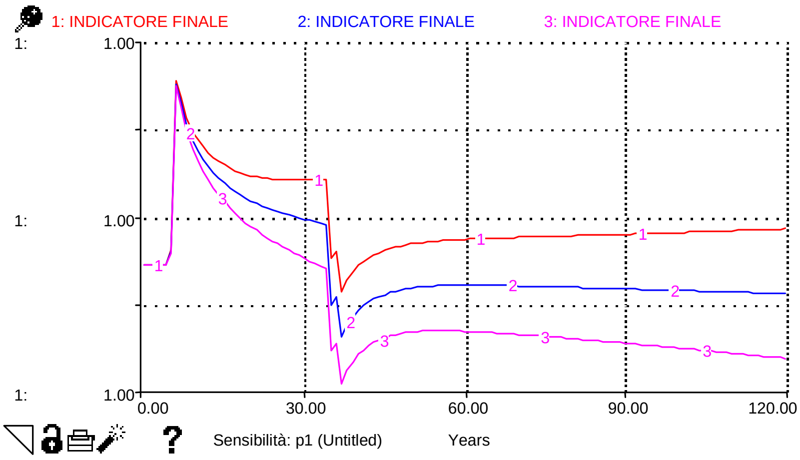


Fig.14



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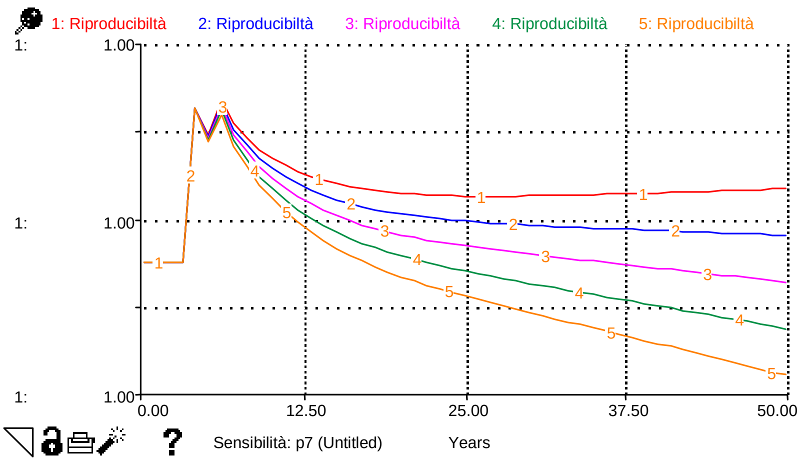


Fig.16

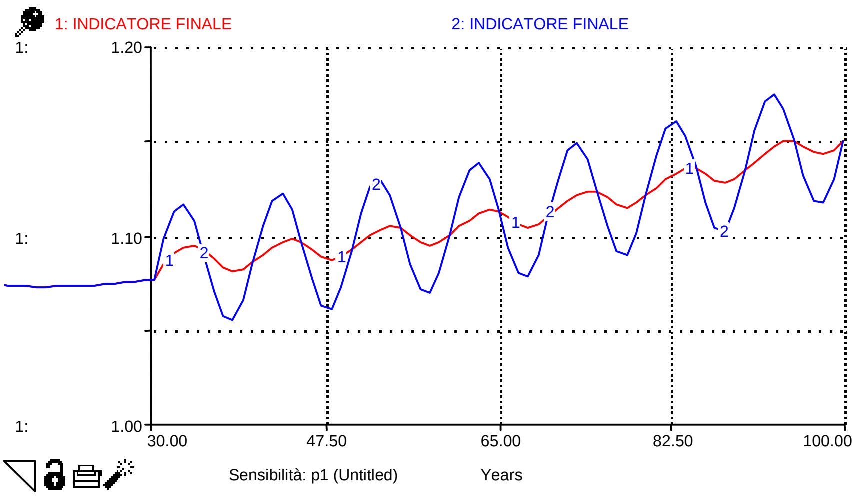


Fig.17

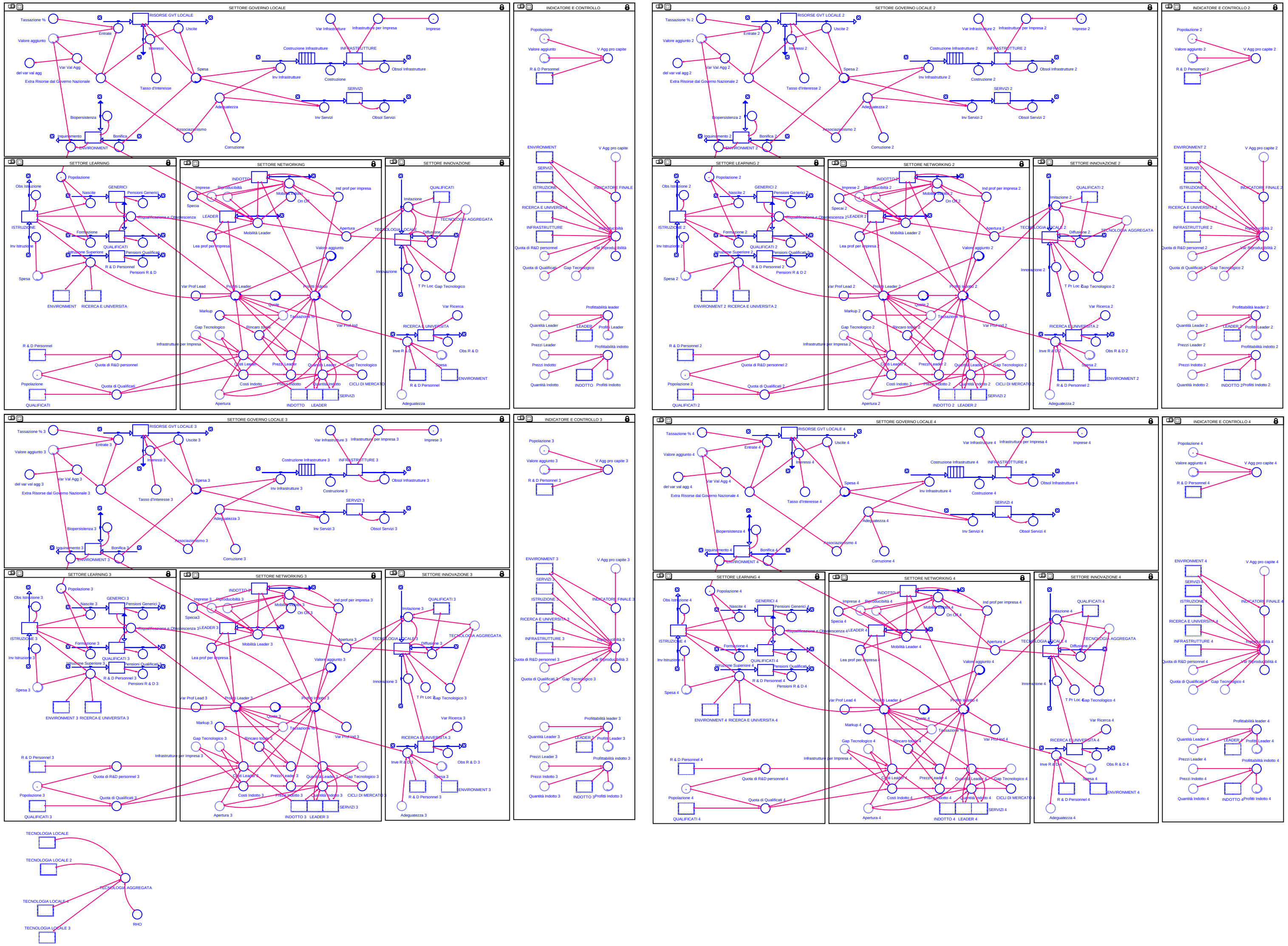
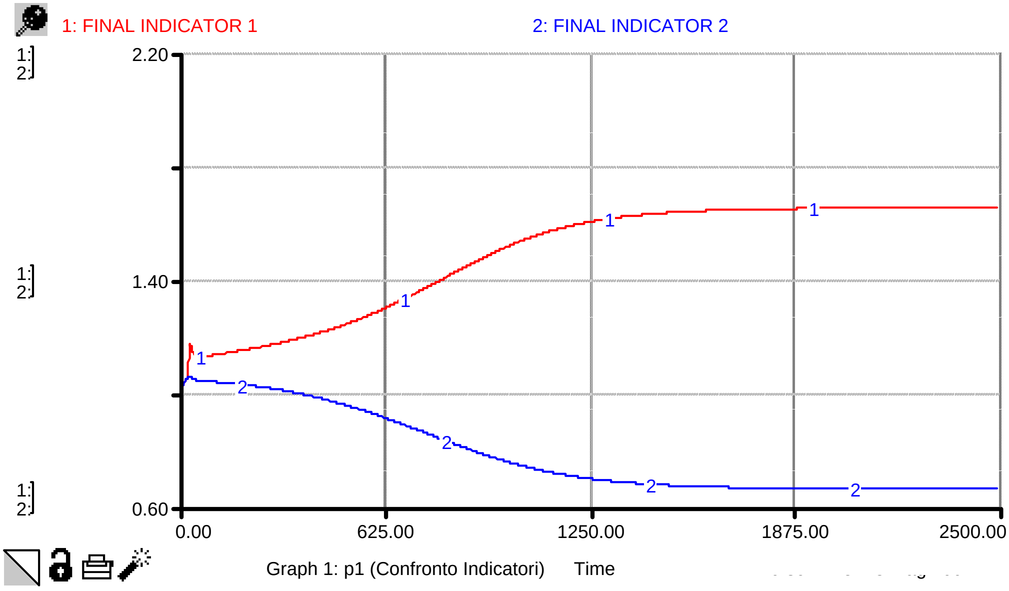


Fig.18 (four models joint)



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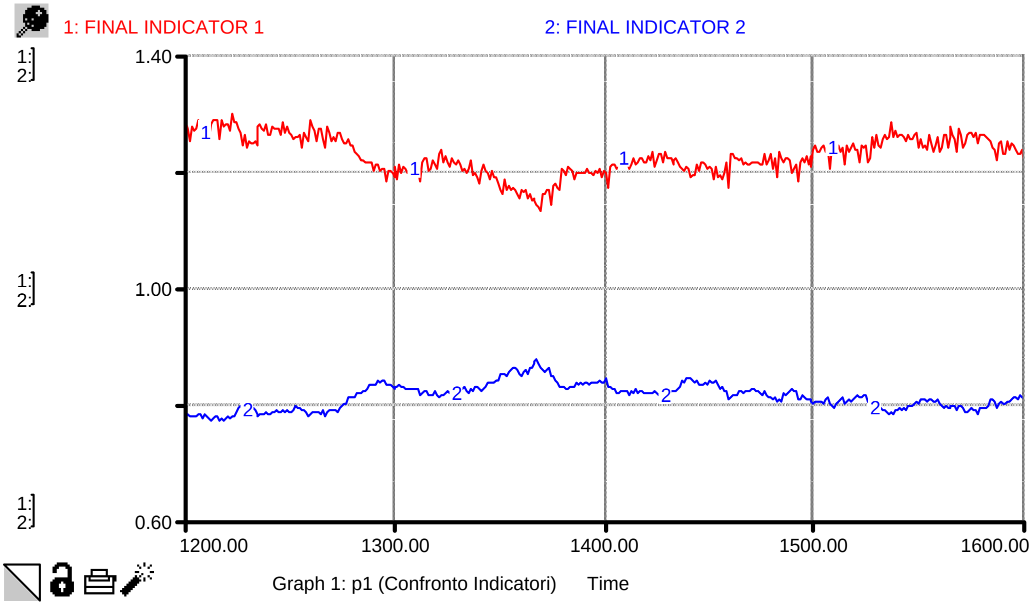

Fig.20

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