A Triple Helix System for Knowledge-based Regional Development: From "Spheres" to "Spaces"

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Abstract
The Triple Helix model is increasingly relevant as a conceptual framework for regional development. Its capacity to describe the process as the result of the joint workings of the University, Industry and Government institutional spheres is expanded by introducing the novel concept of "Triple Helix Spaces": Knowledge, Innovation and Consensus Spaces, which show the process and mechanisms by which the institutional spheres interact and co-evolve over time. The specific activities and formats of the Spaces provide guidelines for integrating endogenous and exogenous strategies. Our objective is to guide policy and practice at various stages in the creation and consolidation of knowledge-based regions.

Introduction

How can aspiring knowledge regions best learn from the world leaders? It is widely recognised that there are no universally-applicable measures for knowledge-based regional development, given widely different conditions in different world regions as, for example, emerging vs. declining industrial regions, urban vs. rural areas, etc. A general model based on a synthesis of contemporary best practice is often relied upon to provide general guidelines that are then more or less adapted to local realities in the attempt to create technopoles, innovative milieus, learning regions, clusters, industrial districts, science cities or regional innovation systems, etc. However, contemporary best practice may not always be the most productive starting point for an aspiring region, as it sets the bar very high and often ignores the early developmental phases that may be more relevant to an emerging region. Simply taking a mechanism that has been highly successful in one area and recreating it in another may not work. Rather than imitating features of late development stages in the life cycle of successful knowledge regions around the world, emerging regions may benefit more from adopting a model abstracted from the formative stages of such successful cases, and adapting it to the strengths, weaknesses and opportunities of the region. This would help avoid the mistake of taking the end result of a knowledge-based growth process for the start and ignoring the long-term nature of endogenous development.

An immanent Triple Helix-based approach to regional development originated in Boston during the Great Depression of the 1930s (Etzkowitz, 2002), and has since

spread across the US and further afield to Europe, Asia and Latin America providing a dynamic framework for the interaction of a variety of institutions and stakeholders, broadly encompassed by 'University', 'Industry' and 'Government'. The positioning of the institutional spheres with respect to each other and their potential for movement and reorientation exemplifies the dynamics of the model, with one serving as a gravitational centre around which the others rotate, thus generating several Triple Helix configurations. For instance, in a *statist regime (Triple Helix I)*, government plays the lead role, driving academia and industry. In a *laissez-faire regime (Triple Helix II)*, industry is the driving force, with the other two spheres as ancillary support structures. In a knowledge-based society, university and other knowledge-producing institutions play an increasing role, acting in partnership with industry and government and even taking the leadership in joint initiatives, in a balanced model *(Triple Helix III)* (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2008). If the workings of the Triple Helix I, II and III regimes are relatively well explored and are usually examined at a specific moment in time (a synchronic interaction), a methodology for analyzing the transition among Triple Helix regimes over time (a diachronic interaction) is a relatively under-conceptualized problem.

In this theme paper, we aim to fill this gap and explain the transition among Triple Helix configurations by introducing the concept of *'Triple Helix Spaces': Knowledge, Innovation and Consensus Spaces* that describe the boundary-spanning diachronic interaction among institutional spheres in the process of constructing knowledge-based innovation systems, in particular from the *laissez-faire* regime (independent spheres, Triple Helix II) to the balanced model (interdependent spheres, Triple Helix III) (Etzkowitz, 2003). Our vision of spaces reflects the sense conveyed by the Finnish notion of "tila" as space, mode, status, but also passage from one status to another. The paper is organized as follows: after a brief discussion of the Triple Helix relevance for regional development, we introduce the concept of Triple Helix systems, defined as a set of components, relationships and functions. We then discuss specific activities and formats of the Knowledge, Innovation and Consensus Spaces and the non-linear dynamics of the possible transitions between them. We conclude with the policy implications of balancing between exogenous and endogenous approaches to regional development.

1. The Triple Helix and regional development

The creation and consolidation of knowledge-based regional innovation systems is the objective of Triple Helix theory and practice. Knowledge-based regions like Silicon Valley and Route 128 do not occur through spontaneous generation; they are the result of initiatives that took decades to reach fruition. In contrast to biological evolution, which arises from mutations and natural selection, social evolution occurs through institution formation and conscious intervention. The Triple Helix provides a means to guide efforts, from different starting points, to achieve the common goal of knowledge-based economic and social development. The result is a tripartite model, with intermediate mechanisms, that integrates the two traditional starting points of science and technology policy: government and industry, with a new element-the university.

A 12th century institution dedicated to conserving and transmitting knowledge became the research university, focused on producing new knowledge in the 19th and early 20th centuries, and then the entrepreneurial university, with a remit for economic and social

development, in the late 20th and early 21st century. The non-linear movement from the teaching and research university to entrepreneurial formats is an emergent phenomenon that is being charted even as it is being realised in various academic systems: US, Europe, Latin America, Asia (Etzkowitz, 1983; Benner and Sandstrom, 2000; Shane, 2004; Wright et.al. 2007; Wong, 2007; Maculan and Mello, 2009).

Government intervention is also essential, on the one hand by encouraging the development of entrepreneurial universities, with the organizational capacity to take leadership roles in their regions, and on the other, by setting the rules of the game, for example by structuring intellectual property, regulatory and tax systems to foster new enterprises. Establishing agencies, like Sweden's VINNOVA, to encourage universities, industry and regional authorities to promote growth projects is another important step. Innovation policy is thus directed toward enhancing the interaction between human needs and research goals, university, industry and government. Schumpeter's theory of creative destruction shows how outmoded economic regimes disappeared; the Triple Helix delineates how new regimes appear.

In the following, we propose the Triple Helix Spaces – Knowledge, Innovation and Consensus - as part of a methodology for generating a Triple Helix Innovation System. The concept derives from the experience of New England Council from the 1920s to 1950s as a summit organisation representing regional leadership that included academia, next to industry and government, because this region had an early and unique concentration of academic resources including MIT, Harvard and a wide range of other academic institutions—"the Knowledge Space". The remit of the Council -"the Consensus Space", created by the Governors of the six New England states was to develop a strategy for the renewal of a region that had been in economic decline from the early 20th century due to departure of industries and firms to regions with sources of raw materials and possessing cheap labour.

After initial attempts to attract branch plants and renew SMEs in dying industries, the Council turned to the region's unique resource and comparative advantage, its high concentration of academic resources. They focused upon the start-up phenomenon of firms emanating from MIT and Harvard in scientific instruments from the turn of the century and in the newly emerging radio industry in the 1920's and invented the venture capital firm to expand and intensify this process -"the Innovation Space". Capitalizing on the region's knowledge resources became the central thrust of a strategy that has since become known as knowledge-based regional economic development (Etzkowitz, 2002).

In addition, information about the creation and working of the "spaces" draws upon recent Mexican, Brazilian, Canadian and Swedish experience, particularly derived from the first author's interviews with members and observers of various projects in Silicon Valley, Rio de Janeiro and Amsterdam, participation in meetings at the New York Academy of Sciences during the mid 1990's, interviews with members of a "space" in Niteroi, Brazil in 2002 and archival research in San Diego and Boston. This data collection through interviews, participant observation and archival research showed that what was initially considered to be the unique historical experience of New England was in fact a broader phenomenon. This course of development, replicated in various ways in knowledge-based economic development projects globally, allowed the New England experience to be generalised into a theoretical model with broad implications.

Triple Helix spaces and spheres, working in tandem provide the engine for regional renewal. A process that appeared to be opaque and hidden can now be revealed by "showing the workings of the engine".

2. Towards Triple Helix Systems: From Spheres to Spaces

Analytically, the Triple Helix model has been conceptualised as two complementary institutional and communication frameworks that reflect two different, yet related, issues, i.e. creating the societal conditions for discontinuous innovation, and better understanding the "normal" operation of University-Industry-Government interactions through constructing more precise indicators, or, in Kuhnian terms, "paradigm shift" versus "normal science" (Kuhn, 1962):

(i) The *institutional framework* primarily focuses on understanding the dynamics of a *balanced* model of overlapping spheres through case studies and comparative historical analysis (e.g. Etzkowitz, 2003, 2008). It is at the intersections of the spheres where "innovation in innovation" takes place, as individual and organisational actors "take the role of the other" (Etzkowitz and Leydesdorff 2000; Etzkowitz, 2008), create new venues for interaction and invent new organisational formats. Through this creative process, the relationships among the spheres are continuously reshaped in "an endless transition" to enhance societal innovation (Etzkowitz and Leydesdorff, 1998). University plays an enhanced role in a knowledge-based society, due to several specific features:

- *The traditional university functions of teaching and research functions, to which a third function of involvement in socio-economic development has been added in recent years ('third mission').* The 'third mission' is to a large extent the effect of stronger government policies to strengthen the links between universities and the rest of society, especially business, but also an effect of firms' tendency to use universities' research infrastructure for their R&D objectives, thus indirectly transferring part of their costs to the state which provides a large part of university funding (Slaughter and Leslie, 1997). Collaborative links with the other Triple Helix actors have enhanced the central presence of universities in the production of scientific research over time (Godin and Gingras, 2000), disproving former views that increasing diversification of production loci would diminish the role of universities in the knowledge production process (Gibbons et al. 1994). Universities are also extending their teaching and research capabilities from educating individuals to shaping organizations in entrepreneurial education and incubation programmes, and provide new teaching and research formats exemplified by inter-disciplinary centres and hybrid organizations such as science parks, academic spin-offs, incubators and venture capital firms (Etzkowitz, 2008).
- *Students' potential to provide new ideas and entrepreneurial talent*. Students may also be trained and encouraged to become entrepreneurs and inspired to take up new roles as firm founders in a society that has become overly dependent on a small set of large corporations, some of which are "dinosaurs" that are becoming extinct, while others have moved significant parts of their enterprise abroad.
- *Universities' capacity to generate technology*. Heretofore primarily seen as a source of human resources and knowledge, universities are now

looked to for technology as well, as many of them developed internal organizational capabilities to formally transfer technologies rather than relying solely on informal ties.

(ii) The *communication framework* focuses primarily on explaining the dynamics of the *laissez- faire* model, with its loose interconnections among independent (non-overlapping) institutional spheres, each with a specific function, which increasingly communicate through an overlay of recursive networks and organizations that reshape the institutional arrangements among universities, industries and government agencies through reflexive sub-dynamics (e.g. markets and technological innovations): *"The functional communications can sometimes be codified in new institutional settings; the institutional sectors (public, private and academic) that formerly operated at arm's length are increasingly working together, with a spiral pattern of linkages emerging at various stages of the innovation process"* (Etzkowitz and Leydesdorff, 1995, p. 15). These sub-dynamics are continuously reconstructed through discussions and negotiation and are driven by market forces, political power, institutional control, social movements, technological trajectories and regimes of intentions, strategies and projects, all adding surplus value to the underlying infrastructure. The interacting sub-dynamics also select upon each other asymmetrically, e.g. markets and networks select upon technological feasibilities, governments can help create a new market or change the rules of the game (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000).

In the communication framework, University, Industry and Government are seen as co-evolving sub-sets of social systems, which are distributed and unstable. They are also *selection environments,* and the institutional communications between them act as *selection mechanisms,* which may generate new innovation environments**,** ensuring thus the 'regeneration' of the system, due to the new combinations in a locally distributed mode. Knowledge generation, diffusion and use emerge as a result of two processes of communication and differentiation*: (i) a functional* one, between science and markets, and (ii) *an institutional* one, between private and public control at the level of universities, industries and government, which allow various degrees of selective mutual adjustment (Leydesdorff and Etzkowitz, 1996, 1998). In addition, i*nternal differentiation* within each institutional sphere generates new types of links and structures between the spheres, such as industrial liaison offices in universities or strategic alliances among companies, creating new network integration mechanisms (Leydesdorff and Etzkowitz, 1998).

In the communicative framework, empirical models inspired by the theory of social systems of communication (Luhmann, 1984) and mathematical theory of communication (Shannon, 1948) have been proposed over the last decade or so for the formalization and operationalization of non-linear dynamics of Triple Helix interactions: market selections, innovative dynamics and network controls operate on various University-Industry-Government configurations through negotiations and translations at the interfaces, using their respective codes of communication and inducing adaptation mechanisms in the institutional arrangements (e.g. Leydesdorff, 1996, 1997, 2000, 2008; Leydesdorff and Meyer, 2006; Dolfsma and Leydesdorff, 2009). The activities of the Triple Helix actors are measured in terms of probabilistic

entropy[1], which, when negative, suggests a self-organizing dynamic that may temporarily be stabilized in the overlay of communications among the carrying agencies (e.g. Leydesdorff, 2003; Leydesdorff, Dolfsma and Van der Panne, 2006). Also, University, Industry and Government selections upon each other generate configurational information (i.e. characteristic to a specific university-industry-government configuration) that can be stabilized and/or globalized, and provides a measure of synergy within a complex system (Leydesdorff, 2008).

The influence of institutions and institutional arrangements on the selection environments in terms of outputs is also a key issue, as a one-to-one correspondence between institutions and functions is no longer possible and enhanced synergies among different selection environments can be expected as a result of institutional arrangements. A *carriers-functions* conceptual framework of Triple Helix sub-dynamics was proposed to examine this phenomenon from a combined neo-institutional and evolutionary perspective, suggesting that the Industry, University and Government *carriers* perform the *functions* of: (i) wealth generation, (ii) novelty production, and (iii) normative control (Leydesdorff and Martin, 2006) (Table 1).

Table 1: A (neo-) institutional vs. an evolutionary appreciation of the Triple Helix model

Sub-dynamics	
Functions:	Wealth generation; Novelty production; Normative control
Carriers:	Industry—University—Government

Source: Leydesdorff and Martin (2006), p. 1442

Although the social and information systems theories that have been used to describe Triple Helix communications suggest an implicit systemic nature of the interaction (University, Industry and Government are seen as sub-sets of social systems), an explicit definition of Triple Helix systems has not been provided so far.

In this paper, we aim to fill this gap and define Triple Helix Systems in a similar way to Innovation Systems[2], which are usually conceptualised in terms of *components, relationships and functions (attributes)* (Carlsson et al. 2002; Bergek et al. 2008; Markard and Truffer, 2008). In a Triple Helix system, *components* include the institutional spheres of University, Industry and Government, with a number of actors related to each sphere; *relationships* encompass a complex mix of links associated on the one hand with collaboration and conflict moderation, and on the other, with substitution; and *functions (attributes)* are defined in terms of a novel concept that we

[1] The term 'entropy' is used here in the information theory sense of the Shannon entropy**,** which is a measure of the uncertainty associated with a random variable and quantifies the information contained in a message, usually in units such as bits (Shannon, 1948). It may also be useful to consider the thermodynamics and statistical mechanics sense of 'entropy', as a measure of the number of random ways in which a system may be arranged, often taken to be a measure of "disorder" (the higher the entropy, the higher the disorder). Some scholars (e.g. Edwin Jaynes) see thermodynamics as an application of Shannon's information theory: i.e. an estimate of the amount of further Shannon information needed to define the detailed microscopic state of the system.

[2] We are aware that the various analytical and methodological difficulties related to the definition of Innovation Systems such as defining the level of analysis to which a system approach is applied, defining the system boundaries, or measuring the system performance (e.g. Carlsson, 2002) also apply to Triple Helix systems. Some of these aspects (e.g. the level of analysis and the system boundaries) are clarified in Section 3 by providing a more fine-grained description of a Triple Helix system.

call the *"Triple Helix Spaces": the Knowledge, Innovation and Consensus Spaces*. The spaces are seen as the physical, but also virtual areas in which the three selection environments of industry, academia, and government interact. They also specify the mechanisms by which the interaction takes place over time, in order to realise the three sub-dynamics (functions) identified by Leydesdorff and Martin (2006) in the communication framework, i.e. (i) novelty production, (ii) wealth generation and (iii) normative control, to which they are associated.

The definition of the spaces as functions of Triple Helix systems also resonates with similar (sub)functions (e.g. Hekkert et al, 2007; Bergek et al., 2005) or activities of Innovation Systems (e.g. Chaminade and Edquist, 2005), where activities are defined as "the factors that influence the development, diffusion, and use of innovations" (Edquist, 2005, p. 182) (Table 2):

Table 2: Sub-functions – or activities – of innovation systems

Hekkert et al. (2007)	Bergek et al. (2005)	Chaminade and Edquist (2005)
Entrepreneurial activities	Entrepreneurial experimentation	Creating and changing organizations
Knowledge development Knowledge diffusion	Knowledge development and diffusion	Provision of R&D Provision of education and training
Guidance of the search Market formation	Influence on the direction of search Market formation	Articulation of quality requirements from the demand side Formation of new product markets
Resources mobilization	Resource mobilization	Incubation activities Financing of innovation processes Provision of consultancy services
Creation of legitimacy	Legitimation Development of positive externalities	Creation/change of institutions Networking and interactive learning

Source: Markard and Truffer (2008), p. 602

3. Structure of a Triple Helix system

We define a Triple Helix system as a set of components, relationships and functions (attributes), as follows:

- ***Components***: ***the institutional spheres of University, Industry and Government***, as an expansion from the dyad of industry and government as primary institutions of the industrial society, to a triad of primary institutions specific to a knowledge–based society. Here, it is important to differentiate between the actors encompassed by the three institutional spheres:
  - ***research and development (R&D) performers*** located in universities (academic research groups), Industry and Government (R&D units or departments in firms and public research organizations), as well as performers of the R&D functional equivalent in the arts, which generates artistic and cultural activities created similarly to scientific R&D, but with their own distinct discovery, validation and dissemination procedures. This latter category can be found not only in university, as

the most universal knowledge-producing and disseminating institution that encompasses both the arts and the sciences and occasionally integrates and cross-fertilizes these apparently divergent modalities in interdisciplinary units, like the MIT Media Lab or the Newcastle Culture Lab, the late Andy Warhol's Factory and the Kitchen Performance Space in New York City, as well as IBM's Watson Research Centre, Stanford's Centre for Integrated Systems and similar R&D organisations, but also in the government sphere (e.g. government-funded cultural organizations, etc.);

- ***non-R&D actors***, such as those intervening in the context of design, production, marketing, sales, technology adoption, incremental change, combining existing knowledge in new ways, interaction with users, acquisition of patents and licenses, etc.
- ***hybrid institutions*** synthesizing elements of academia, industry and government institutional design and/or support, which can be both R&D and non-R&D performers, e.g. interdisciplinary research centres, industry-university research consortia, translational research institutes, technology transfer offices in universities, firms and government research labs; business support institutions (science parks, business/technology incubators); financial support institutions for new technology-based firms (public and private venture capital firms, angel networks, seed capital funds, etc.).

- ***Relationships****:* here we distinguish between two main types of relationships as the social evolutionary mechanisms inducing change in Triple Helix regimes:
  - ***Collaboration and conflict moderation*** (including provision of R&D and consultancy services, competence-building, formation of new markets or consolidation of existing ones, creating and changing organisations and/or institutions, networking, technology transfer or acquisition of goods and services through market or non-market interactions, incubation activities, financing, negotiation, etc.). The enhanced potential for coalition-building and conflict moderation are benefits inherent in the formal properties of triadic relationships, and are often lacking in dyadic relationships, which are more subject to collapse into oppositional modes (Simmel, [1922] 1955.)
  - ***Substitution*****:** such relationships arise when, in addition to fulfilling their traditional functions, each institutional sphere may also "take the role of the other" (Etzkowitz, 2008) by filling gaps that emerge when another sphere is weak, or unable or unwilling to enact its traditional role. Examples include a declining industry failing to infuse itself with new technology to seek a path to renewal, or government agencies taking up, in addition to their traditional function of regulation and control (e.g. specification of contract formats as the basis for market operations, or providing for public security and safety at the local and national levels), the provision of public venture capital - a traditional task for the industrial sphere. Similarly, universities, in addition to their teaching and research activities, increasingly engage in technology transfer and firm formation, providing support and even funding to encourage entrepreneurial ventures, thus enacting some of the traditional role of industry. Industry takes the role of the university in developing training and research, often at the same high level as universities.

Moreover, a trend towards *internal substitution within spheres* was observed (Ranga et al. 2008). For example, in situations where the local university is only marginally involved in entrepreneurial activities and links with industry, especially small firms, vocational training institutions may take the lead in such interactions, as they provide a more practical, hands-on, shorter-term oriented education, which is better suited to meet the knowledge needs of the small, non-R&D firms than the programmes of the local university. Similarly, in the absence of R&D- and technology-intensive companies that are usually involved in Triple Helix partnerships, professional associations or chambers of commerce representing the interests of the local business community take the lead in fostering partnerships with academia and government. Such substitutive relationships of institutions taking non-traditional roles are a major potential source of "innovation in innovation" (Etzkowitz, 2003), reflecting the expansion of innovation from an internal process within and among firms to an activity that often occurs within and among the other Triple Helix institutional spheres.

- ***Functions (attributes):*** here, we introduce the concept of ***"Triple Helix Spaces": the Knowledge, Innovation and Consensus Spaces,*** to delineate the physical, but also virtual areas in which the Triple Helix institutional spheres interact, and also explain the mechanisms by which they interact, in a diachronic co-evolution over time, in parallel with their synchronic dynamics. The spaces are related to the three functions of (i) wealth generation, (ii) novelty production and (iii) normative control identified by Leydesdorff and Martin (2006), and are seen as the environments in which these functions are realised.

  The spaces are thus *an attempt to integrate the dynamics of the interdependent institutional and communicative Triple Helix regimes* discussed earlier: novelty production is no longer the function of the University sphere alone, but a joint process between University, Industry and Government; wealth generation is not the sole function of the Industry sphere, but is promoted through the invention of organisational mechanisms that incorporate elements from across the Triple Helix in their constitution; and normative control arises from interaction among the spheres in a Consensus space rather than as a specific function of Government.

4. The formation of Triple Helix Spaces

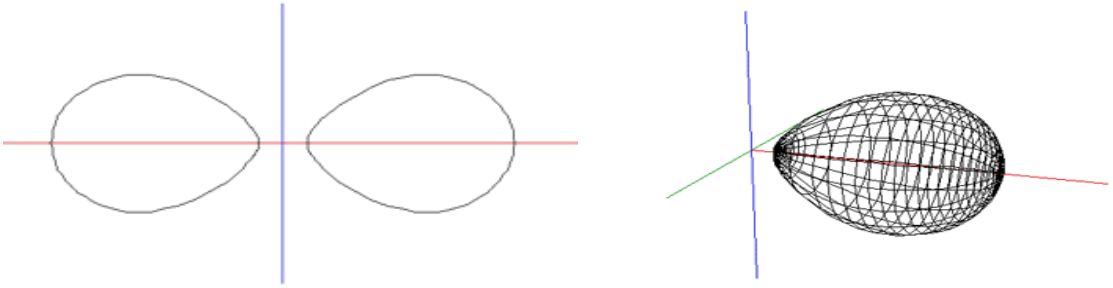
A 2D and 3D visual representation of the interaction between any two of the University, Industry and Government institutional spheres in the process of creating a Space is provided by the *Cassini curves*[3] represented in Figures 1 and 2 below. Figure 1 shows four particular configurations that best illustrate the transition from independent to

[3] The Cassini curves are a family of curves investigated by the astronomer Giovanni Cassini in 1860, which he believed defined the path the Earth takes around the Sun. The curves were defined by all the points where the product of the distances from the point to two fixed points situated at a distance 2a apart is a constant called b^2. The general appearance of the curve is dictated by the relative values of a and b. If a < b the curve forms a single loop. This loop becomes increasingly pinched as a approaches b. When a > b the curve is made up of two loops, at a = b it is the same as the "lemniscate of Bernoulli" that was documented about 14 years later.

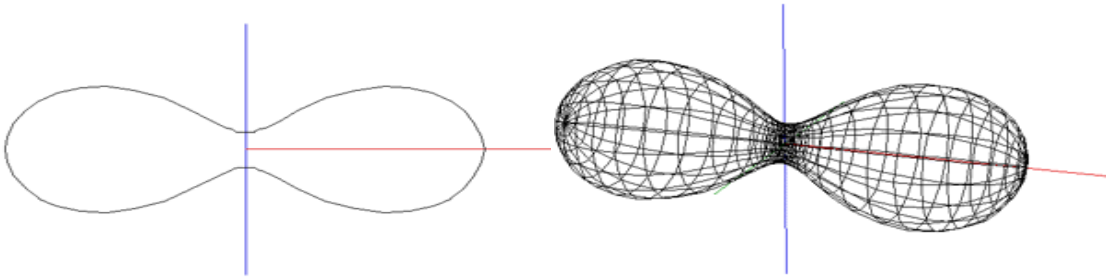
overlapping spheres in the move from a *laissez-faire* (Triple Helix II) to a balanced model (Triple Helix III). The interaction between two spheres could be seen as the fundamental building-block of the process of creating and consolidating a Space; a similar process can be extrapolated from this representation for three institutional spheres. Figure 2 shows an integrated set of Cassini curves that illustrate all the possible configurations of the transition from a *laissez-faire* to a balanced model.

Fig. 1 - Interaction between two institutional spheres in the emergence and consolidation of a Space

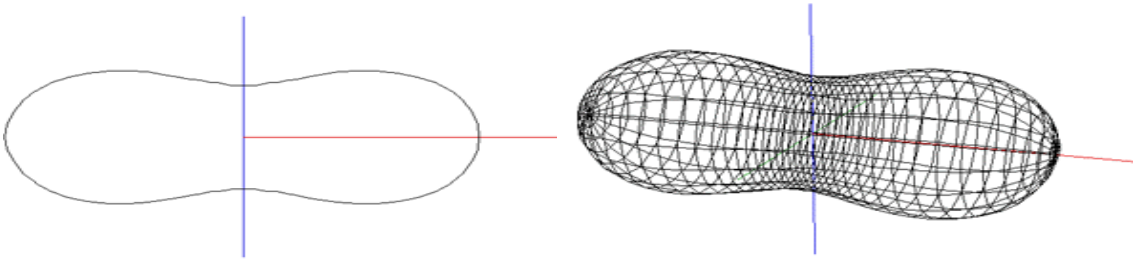
a. Institutional spheres apart: a laissez-faire (Triple Helix II) regime[4] (only one half of the 3D image shown).



b. Institutional spheres getting closer together and starting to interact[5]. Emergence of a Space.



c. Institutional spheres increasingly overlapping[6]. Consolidation of a Space.



[4] For a > b the curve splits into two halves mirrored by the y axis. For example, at a = 1.01, b = 1, one observes an "egg"-shaped configuration. Only one half of 3D image is shown.

[5] At a<b, e.g. a = 0.99, b = 1 the curves overlap into a single loop, like in the configuration represented here, also called a "dog bone". The contact point is reached at a = b, a configuration also called the "lemniscate of Bernoulli".

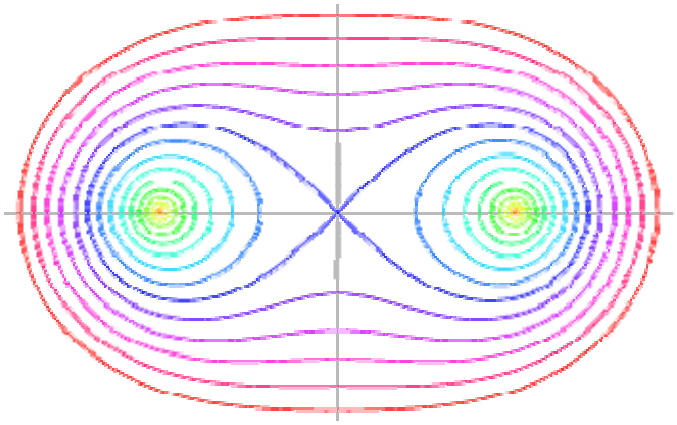
[6] As a continues to decrease in value compared to b, a "peanut"-shaped configuration appears at a = 0.9, b = 1.

d. Institutional spheres overlapped in a balanced mode (Triple Helix III)[7]. Consolidation of a Space

Source: http://local.wasp.uwa.edu.au/~pbourke/geometry/egg/

The overall set of Cassini curves representing the multitude of configurations between two institutional spheres in the formation and consolidation of a Space is presented in Fig. 2:

Fig. 2 - Overall set of Cassini curves



Source: http://mathworld.wolfram.com/CassiniOvals.html

The main features of the Knowledge, Innovation and Consensus spaces are discussed in detail in the next sections.

5. The Knowledge Space

The Knowledge Space is primarily the realm of R&D in science and technology, located in universities, firms and government labs, as well as its functional equivalent in the arts, which generates artistic and cultural activities created through an organised collective process, similar to scientific R&D, but with their own distinct discovery, validation and dissemination procedures. However, non-R&D activities, such as technology adoption, combining existing knowledge in various ways, organizational change, etc., which have been increasingly recognised in recent years to play an important role in improving firm productivity and competitiveness and fostering innovation, can also be included in the Knowledge Space. Relevant evidence in this

[7] At a = 0.5, b = 1, a "melon"-shaped configuration appears, again showing the change of shape as a value continues to decrease compared to b. In the extreme case of a=0, the "melon" (ellipse) becomes a circle, or a sphere in 3D.

respect is provided by the European Innovation Scoreboard 2008[8] on the basis of Innobarometer 2007 Survey, which is based on a quota survey for all the EU27 countries and was partly designed to further investigate the non-R&D activities of European firms. Of the 4,395 innovative firms surveyed, covering the period 2005-2006, *52.5% innovated without R&D (non-R&D innovators),* 40.0% performed R&D in house and 7.5% contracted out R&D to other firms and organisations. The 52.5% share of non-R&D innovators of the Innobarometer 2007 was found to be similar to the 50% share identified by the Community Innovation Survey in the period 1998-2000. Non-R&D innovators were found in all firm size categories, countries and sectors, but with higher incidence in low-tech sectors, small firms (less than 50 employees) and countries with lower innovation performances (European Innovation Scoreboard 2008, pp. 23-24).

This broader picture of the Knowledge Space increasingly supersedes the Knowledge Space of the early industrial society, where informal activities of users and producers in the context of production had a central role, but never entirely replaced it by formal R&D units and highly trained persons in the transition to an increasingly knowledge-based society.

An essential condition for the creation and consolidation of the Knowledge Space is the existence of *a 'critical mass' of* academic research and education resources on a particular topic in a local area, as well as other R&D and non-R&D actors. Therefore, universities and other knowledge-producing institutions from the Industry of Government spheres are central to establishing an effective Knowledge Space. It is the integrative ability of the university, providing a neutral site for other knowledge actors to collaborate, as well as its flow-through of human resources, which increasingly makes it the key actor in the Knowledge Space.

The Knowledge Space encompasses a variety of paths to knowledge-based renewal, based on different local and regional resources. When R&D and educational resources are weak, strategies may be developed to support their development; when they are strong, the focus may be on how to utilize these capacities to enhance knowledge and innovation-based economic growth and improve the competitive advantage of the region. Several trajectories become thus possible for the creation of a Knowledge Space, some of which are exemplified below:

- *Decentralisation of national public research organisations to less research-intensive regions.* This was the case of government research laboratories moved from Mexico City to other regions of Mexico after the mid-1980s earthquake, and inserted into new surroundings where they took on a new potential (Casas, Gortari and Santos, 2000). The researchers started to use their skills and the lab resources to address problems in their new locality. This policy was eventually broadened from a diffusion of research resources to an explicit regional development policy, and more research institutes were transferred from the capital to other regions to give them a research capacity that had heretofore been lacking. Another example of moving existing research resources is North Carolina's Research Triangle - a classic case of using the state's political clout

[8] European Innovation Scoreboard 2008. Comparative Analysis of Innovation Performance. Available at: http://www.proinno-europe.eu/EIS2008/website/docs/EIS_2008_Final_report.pdf (last accessed 4 January 2010)

to gain second level government labs as an attractor of second level corporate labs as the initial framework for high-tech development (Hamilton, 1966).

- *Foundation of a science-based university*, as in San Diego, where a new branch of the University of California was gestated in the 1950s and eventually became the basis for a leading high-tech complex. The attraction of leading researchers in fields with commercial potential, like molecular biology, was early recognized as an economic development strategy by the coalition of academic, business and political leaders that pushed the development of this campus. The transformation of San Diego from a naval base and military retirement community to a knowledge-based conurbation followed. The University of California, Merced has recently been established as an "entrepreneurial university" in an agricultural region with the intention of replicating the San Diego experience of several decades earlier. The strategy, following the classic endogenous model, albeit with significant exogenous support, was to create and then leverage location-specific knowledge assets to induce new investment and create new value.

- *Congregation of geographically dispersed groups from university and industry around common themes, with government support*, such as the Canadian Networks of Centres of Excellence (NCE)[9]. Highly qualified personnel work co-operatively through NCE-sponsored initiatives of industrial relevance. Their work involves everything from leading-edge investigations into the causes of and potential cures for cancer to the use of robots and intelligent systems to perform tasks in difficult environments. The incentive of a large government originally motivated widely dispersed academic and firm research units to work together on a proposal, typically dividing up the funds to extend existing local projects, with a suitable overlay of collaborative rhetoric. However, through the interaction and discussion necessary to get a proposal together s intriguing ideas were produced that led to the transmutation of rhetoric into reality.

- *The functional equivalent of R&D in arts is exemplified by the activities of groups such as the Kitchen in New York City* that invent new artistic formats and modes of performance art and then disseminate them through international performance tours. Thus, "R&D" is often a significant, if under-recognized factor in the development of creative industries, simply because it does not take place in labs with white coated personnel[10]. After-hours clubs have also been recognized as providing venues for artists, fashion designers and other creative individuals to develop new projects across the disciplines, warranting permission to keep late hours in recognition of their economic development mission (Currid, 2007). Movement of artists into abandoned industrial buildings and preserving them as low-cost space by reserving them for qualified persons through creative use of municipal zoning authority regulated the transition of a declining manufacturing district into Soho, the arts equivalent of a Science City project based on advanced academic research (Etzkowitz and Raiken, 1980). Public arts funds and more general public employment schemes supported the

[9] See www.nce-rce.gc.ca/index_eng.asp for further details on the Canadian Networks of Centres of Excellence.

[10] Notable exceptions, albeit without the "uniform" include MIT's Media Lab and its worldwide progeny at IIT Kanpur and Tokyo University and Newcastle University's Culture Lab.

work of many of these artistic and cultural organisations which provided the infrastructure that led to the transformation of abandoned industrial sites into chic neighbourhoods. Ironically, they often became too expensive for their pioneers, driving them to new frontiers of declining neighbourhoods elsewhere in the city and region. The phenomenon has been recognised to the extent that municipalities seeking renewal often invite arts groups to relocate to subsidized space in order to jump-start a gentrification process that has become an overlay on arts-based economic renewal.

In developing and analyzing the Knowledge Space of regions, two dimensions can be used to operationalise the concept:

1. Mapping of regional R&D and non-R&D actors (e.g. public and private research labs, firms, universities, arts and cultural organizations, etc.) and analyzing their evolution over time and future trends, understanding their priority-setting and the design of their agendas, scope of operations (regional, national, international) and regional impact.
2. Developing policies and programmes on human resources for R&D in the sciences and arts at national/regional level, including labour market aspects for researchers, employment, education and training, immigration to attract world-class researchers, making research more attractive to various categories of the local population, especially women and minorities, reducing brain drain and improving brain gain at various stages of education and research career.

All the characteristics of the Knowledge Space discussed above, i.e. activities, trajectories and dimensions suggested to operationalise the concept illustrate the association between the Knowledge Space as a function of Triple Helix systems and the novelty production function of the Triple Helix communicative framework discussed in Section 1. These characteristics emphasise the key role of the Knowledge Space in the realisation of the novelty production function, as the result of the joint involvement of actors from all Triple Helix spheres, rather than from University alone, in line with the process of institutional communication, differentiation and integration addressed in Section 1.

The Knowledge Space also illustrates the diachronic interaction between the spheres through the process of continual renewal in which it finds itself, especially at the level of universities. Universities typically replace people who have left or retired with someone with the same or similar skills. For example, in computer science a position may be seen as reserved for someone teaching COBOL, a now historic language in which new developments are not expected, yet it is still important for business use, and the next person is recruited to replicate the knowledge repertoire of the previous occupant of the post. Even though the knowledge area may be outmoded, there is usually a sufficient support-base, as with COBOL, to justify its retention, at least as a teaching area, even if it is no longer cutting-edge. Only by continuously reviewing and rethinking its specialties, both at the level of individual positions, departments and even faculties can universities reinvent themselves to be at the knowledge frontier. Universities have built-in mechanisms of human capital flow-through, such as admission and graduation of students that enhance the chances of organizational renewal in comparison to research institutes and R&D units of firms, which are more static organizational models in comparison to academic research groups.

6. The Innovation Space

The Innovation Space is the venue for recombining elements of existing organisational models together with new concepts for organisational functioning in order to invent better ways to encourage and promote innovation. Activities in the Innovation Space include the aggregation of resources to create the new organisational format, induction of people into newly conceptualised roles and the creation of legitimating themes to justify the enterprise by linking it to both old and new societal goals. At the local level, this space involves the adaptation or creation of new organizations to fill a gap in the regional innovation environment, as well as in other social systems in need of renewal. Such new organizations typically have hybrid formats, synthesizing elements from different institutional spheres, e.g. venture capital firms, science parks, business or technology incubators, created out of elements of academia, industry and government institutional design and/or support.

The appropriate organizational format is a function of the strengths and weaknesses of the region. Further modifications typically involve linking one mechanism to another in a sequence of steps, e.g. incubation leads to entrepreneurship training, and venture capital to incubation. However, the order of steps is not predetermined and depends on local circumstances. For example, an entrepreneurial training programme can come first or follow incubation and venture capital. Furthermore, in a region where venture capital is available, it would not make sense to make that the focus of activity. Building up selected R&D and arts areas with future commercial potential is a useful strategy both for emerging regions to jump-start knowledge-based development and highly developed regions seeking to maintain their competitive edge.

The common characteristic of the Innovation Space organizational formats is the *knowledge-based entrepreneurship* that is enacted as an institutional phenomenon encompassing all the Triple Helix actors. They can undertake collaborative projects to enhance the regional innovation environment and improve its abilities to serve as the take-off platform for business ventures. Lacking such an environment, a firm will be deprived of "oxygen" and be forced to move to a more supportive local context. For example, a Northeast UK inventor with a technology similar to that of SUN Microsystems found that he was unable to move his technology forward locally, sold his firm to SUN and moved to Silicon Valley for a period of time to transfer his technology.

Entrepreneurial innovation is the change-inducing force and a driver of regional development that can arise from various sources. It can be built from various cultural foundations[11] and relies on values, attitudes and behaviours that can be combined with various policy measures to foster a strong entrepreneurial orientation. It is also influenced by the motivation, aptitude and level of economic and technological performance of the region (Thwaites and Wynarczyk, 1996; Lee and Peterson, 2000), which can be strengthened by effective entrepreneurial training programmes and business plan competitions. Indeed, such support measures may be found worldwide, from Sweden to Brazil. Their widespread growth recognizes that an entrepreneurial orientation is critical for the economic prosperity of a variety of localities, regions and nations (Morris, 1998).

[11] For example, Sombart (2001), in his analysis of the Catholic merchants of Bruges, found similar entrepreneurial characteristics to those that Max Weber (2003) identified in his classic work *The Protestant Ethic and the Spirit of Capitalism.*

The concentration of entrepreneurial talent, intellectual capital and tacit knowledge in a relatively few world-class regions gives them a clear competitive advantage in drawing talent and innovative firms into their orbit from emerging regions. For instance, Silicon Valley is noted for its relative strength in semiconductors and software, while Boston is widely recognised, formerly for minicomputers and presently for biotechnology. This clustering reflects the economies of scale generated by locating in the same area as other firms working on similar technologies or products (Feldman and Francis, 2004). Location advantages of successful high-tech regions are a result of a long-term development process, based on local entrepreneurial capacities and institutional support for new firm formation and innovation (Mason and Harrison, 1992). Other regions with agglomerations of research resources, like New York and Chicago, largely failed to develop commensurate high-tech clusters, to date. Nevertheless, in the wake of the downturn of New York's financial industry, steps are being taken to build alternative economic drivers on the regions extensive research base.

In developing and analyzing the Innovation Space, two dimensions are suggested:

1. Technology transfer institutions (e.g. technology transfer offices in universities, in firms and in government research labs, industrial liaison offices), business support institutions (e.g. science parks, business/technology incubators) and financial support institutions for new technology-based firms (public and private venture capital firms, angel networks, seed capital funds, etc.).
   They provide the organisational design and policy impetuses that move intriguing organizational design models from prototypes into broad platforms, by inserting elements that facilitate and encourage implementation and utilization, thereby generalizing the original, often unique, instance. This may involve a training and human capital formation process, a financing scheme and a legitimatory framework to create status and acceptance for the organisational invention.

2. Policies to promote the formation and activity of the institutions above:
   - Policies supporting partnerships between university, public research institutions and industry, in particular SMEs, establishment of science parks, incubators, business/technology incubators, seed funds and new types of public-private partnerships.
   - Policies to increase participation of industry and other stakeholders in public research priority-setting.
   - Policies related to the intellectual property rights (IPR) regimes governing the ownership, licensing and exploitation of IPR resulting from publicly-funded research, promotion of technology transfer to industry and spin-off creation, IPR awareness and training activities targeting in particular the research community.
   - Fiscal measures to encourage the creation and growth of R&D-intensive firms and raise attractiveness of research careers, etc.
   - Support to guarantee mechanisms for research and innovation in SMEs (equity investment of venture capital funds or loans, national and regional programmes to improve access to debt and equity financing for research and innovation activities, increasing awareness of research-intensive SMEs about the use of risk capital, notably through actions at regional level).

Similarly to the Knowledge Space, all the characteristic aspects of the Innovation Space discussed here, i.e. activities, organizational formats and dimensions suggested to

operationalise the concept illustrate the association between the Innovation Space as a function of Triple Helix systems and the wealth production function of the Triple Helix communicative framework. These characteristics emphasise the key role of the Innovation Space in the realisation of the wealth production function, as the result of the joint involvement of actors from all the Triple Helix spheres, rather than from Industry alone, in line with the process of institutional communication, differentiation and integration previously discussed.

The diachronic co-evolution of the Triple Helix institutional spheres the Innovation Space is also exemplified by the constant expansion and adjustment taking place in this space. When a university takes an initial step in establishing a liaison or technology transfer office, it soon realizes that a much broader range of services and support structures are required in order to market intellectual property and create spin-off firms. Sometimes, this involves inserting the new innovation mechanism into a broader institutional environment such as a national or European-wide network of transfer offices in order to identify market opportunities and partners. Other times, an alliance with local city and regional governments may pave the way to funding an incubator facility to assist in spinning off firms. Innovation is a never-ending process and the innovation space is insatiable in its demands. This explains why the state of California recently passed a $3 billion stem cell research initiative to strengthen the biomedical research capacities of its universities, combined with programmes directed at enhancing the availability of venture funds and assistance to start-up firms. Debt-funding mechanisms, previously utilised to develop moderate-income housing, were adapted to generate research funds and public venture capital (Etzkowitz and Rickne, 2009).

7. The Consensus Space

The Consensus Space is at one and the same time, the physical space, convening platform and virtual framework that brings together the Triple Helix actors to brainstorm, discuss and evaluate proposals for advancement towards a knowledge-based regime. Through cross-fertilizing diverse perspectives, arising from different standpoints, ideas may be generated and results may be achieved that actors could not likely have accomplished individually. In the Consensus Space, Triple Helix actors come together to formulate strategies to initiate projects for realising and enhancing the local growth potential, Thus the Consensus Space becomes a binding element between the Knowledge and Innovation Spaces that may often exist, but interact in a fragmented and disarticulated way.

This is essentially a governance space, in the sense of governance defined by Kuhlmann (2001, p. 957) as *"a process through which a socio-political community achieves binding decisions in the face of conflicting interests. The processes of consensus-building, decision-making or even implementation of decisions are not merely determined by state actors or formal governments. Rather, due to growing complexity and segmentation of modern societies and issue areas, it is the interaction of societal and state actors that defines problems, builds up the necessary degree of consensus on problems and solutions, consolidates conflicting interests and (pre-)determines political decisions"*.

Indeed, the Consensus Space is a mix of top-down and bottom up processes to create leadership through collaboration rather than diktat, a neutral ground where the different

actors in a region, from different organizational backgrounds and perspectives, can come together to generate and gain support for new ideas promoting economic and social development. A process of "cross-institutional entrepreneurship" spanning the Triple Helix spheres is thus initiated and aims at improving the conditions for knowledge-based regional development.

The process of getting relevant actors to work together often includes the creation or modification of an organization to provide a home for brainstorming, analysis of problems and formulation of plans. Examples include the Pittsburgh High-Tech Council or the Petropolis Technopole in Rio de Janeiro State (Mello and Rocha, 2004), or the Board of the Recife Brazil Science Park, explicitly representing key actors in regional innovation and playing a "quasi-political" role for enhancing innovation capacity in the region. In addition, the very process of including actors from different backgrounds in the strategy review and formulation process may provide access to the resources required to implement a project. An example in this sense is the New England Council representing university, industry and government leadership in the region, which invented the contemporary format for the venture capital firm, building upon family investment firms with a professional staff. They worked out a political strategy to make the venture capital firm a viable entity by lobbying to change laws that prevented large financial institutions from investing in risky ventures. Another example is an informal group of academics and entrepreneurs in Rio de Janeiro that came up with the idea of starting a PhD-oriented new campus of the State University of Rio de Janeiro in Friburgo to provide a neighbouring declining industrial region with high-level knowledge inputs, rather than simply training support personnel for existing firms as might have happened in an undergraduate campus. Similarly, the Knowledge Circle of Amsterdam meets regularly to brainstorm ideas for enhancing knowledge-based development.

Government and its agencies may play an important role in shaping the Consensus Space, as, for example, the Governors of the New England States' founding of the New England Council in the 1920's. They encouraged a range of public, semi-public, civic and private actors to bring their resources into the system of governance and shape the Consensus Space. However, when government structures are less active, universities, industry associations and NGO's may take the leadership role in creating a venue that brings relevant actors together to address innovation issues and gaps. Thus, Birmingham University provided an ideal neutral site for the deliberations of a consortium of Triple Helix actors in projecting the post-Rover, post-automotive future of the west-Midlands, UK as a future technology corridor including a biomedical complex based on area research resources. A boundary-spanning leadership, capable of transcending entrenched local interests, was found to be crucial to this endeavour (Gibney, Copeland and Murie, 2009).

The Consensus Space is characterised by:

- Interdependence between organizations; rather than seeing themselves as isolated entities, firms, academic institutions and local government actors begin to see themselves as part of a larger whole: in some cases a newly invented identity like Oresund; other times a reviving traditional locality like Norkopping, Sweden.
- Broader coverage of the governance concept, including government as well as non-government actors;

- Changing boundaries of the state, with shifting and more transparent boundaries between public, private and voluntary sectors;
- Continuing interactions between network members, caused by the need to exchange resources and negotiate shared purposes;
- Game-like interactions, rooted in trust and regulated by the rules of the game negotiated and agreed by network participants;
- A significant degree of autonomy from the state;
- Networks are not accountable to the state; they are self-organizing; and
- Although the state does not occupy a privileged, sovereign position, it can indirectly and imperfectly steer networks.

The Consensus Space is also closely related to the concept of *leadership,* which cuts across all the Spaces. At the regional level, an Innovation Organizer - an individual/and or group - sets forth a future achievable objective. The Innovation Organizer typically occupies a key institutional position, who enunciates a vision for knowledge-based development and who has sufficient respect to exercise convening power to bring the leadership of the institutional spheres together to aggregate and commit resources to implement a project emanating from what becomes a shared vision if and when the process takes on momentum. In 1930's New England MIT's President Compton filled this role; in the 1990's Silicon Valley downturn a respected CEO took the lead as convenor. Who shall assume a leadership role at the regional level is a frequently asked question even in countries with strong regional governments. In countries with no or only weak regional governments, there may not be a governmental actor available to take the lead at the regional level, but other actors, such as universities and firms, may come forward to take the Innovation Organizer role.

As in the cases of the Knowledge and Innovation Spaces, all the activities and key features of the Consensus Space discussed here illustrate the association between the Consensus Space as a function of Triple Helix systems and the normative control function of the Triple Helix communicative framework. The Consensus Space appears to play a key role in the realisation of the normative control function, as the result of the joint involvement of actors from all the Triple Helix spheres, rather than from Government alone, in line with the process of institutional communication, differentiation and integration.

The diachronic co-evolution of the Triple Helix spheres within the Consensus Space is exemplified by the dynamics arising from the application of "multi-level governance" (Hooghe, 1996; Marks et al., 1996; Cooke et al., 2000), which manifest themselves in different ways at the supranational (e.g. EU, NAFTA), national, regional or urban levels. For example, in Europe, we assist at an increasing process of devolution of central powers to regional and local administrations, in parallel with an increasing role of European Union policies at national and regional level, which raises several hypotheses concerning the co-evolution of "political systems" and "innovation systems" in Europe (Kuhlmann, 2001).

8. Non-linear Dynamics of the Spaces

The Knowledge, Consensus and Innovation Spaces can be created or organized in any physical space or time order, exemplifying how the selection mechanisms act upon each other and generate variance for each other. Thus, selection and variation among and

within the spaces ensure their 'mutual shaping' or co-evolution. For example, in the wake of deindustrialization, Norkopping Sweden established a Council representing the city region's business and political leadership and decided to focus on creating a university campus with advanced academic research groups in order to revive one of its traditional industries (Svensson, Klofsten and Etzkowitz, 2010). Thus, in this case the sequence was Consensus->Innovation->Knowledge Space in contrast to the New England sequence of Knowledge->Consensus->Innovation. A matrix of potential pathways may be constructed. They can be the result of successive initiatives, building upon and revising previous explicit or immanent strategies, rather than appearing as unique outcomes of singular path-dependent events.

Transitions among the spaces are hypothesized to occur in different directions as a non-linear process, starting from any space in different regional circumstances. It is expected that less research-intensive regions will focus on strengthening their Knowledge Space, while industrial regions with a high level of R&D resources will focus on the Innovation Space to develop specific initiatives. The Consensus Space is hypothesised to catalyse the formation of Knowledge and Innovation Spaces when they are not present. Nevertheless, the speed of the transition from one space to another depends on the reaction time of each individual space; the spaces remain structurally coupled to various extents and cannot evolve independently, as they depend on the underlying communications between the actors involved. The transition progresses on the basis of "*chances that are redistributed as a result of previous rounds of communication. The ongoing communications not only inform the communicators, but also update the distributions in the communication system*." (Leydesdorff, 2001, p. 9) This is another element that emphasises the capacity of the spaces to bridge the institutional and communicative Triple Helix frameworks discussed in Section 1, next to the central role they play in the realisation of the novelty production, wealth generation and normative control functions defined in the communicative framework.

This dynamics of the transition among Triple Helix spaces is highly visible in the transition among stages of regional development. Elsewhere (Etzkowitz and Klofsten, 2005) we outlined a four-stage model of regional growth and renewal, as follows:

(i) Genesis: creating the idea for a new regional development model;
(ii) Implementation: starting new activities and developing infrastructure;
(iii) Consolidation and adjustment: integration of activities to improve the efficiency of the infrastructure;
(iv) Self-sustaining growth and renewal of the system by identifying new areas of growth.

At the Genesis stage, a key issue is the state of the Knowledge Space, which can already exist or must be created or enhanced. A comparison among the New England, Linkoping and Friburgo cases is instructive. In the first, the Knowledge Space was significant; in the second, moderate, and in the third it was virtually lacking. In these cases, appropriate conclusions were drawn: the New England Council moved directly to the Innovation Space to promote commercialisation. In Linkoping, in order to extend mechanical expertise into emerging areas, an interdisciplinary university was started to promote interrelations and interconnections, as well as development of new fields like computer science. In Friburgo, a tightly focused advanced academic programme was created in order to infuse new knowledge into traditional industries. The Knowledge Space is also especially salient at the point of the Self-sustaining growth and renewal

phase. This was especially noteworthy in Silicon Valley in the mid 90's, where many successful firms had outgrown their university links, or were spinoffs of an early generation of firms and had never developed extensive academic links. Indeed, by this time, many of the Valley's high tech firms tended to view themselves as a self-generated phenomenon, a cluster of inter-related firms, rather than as part of a broader university-industry-government complex. However, in the mid 90's downturn, such firms felt the need to connect or reconnect to academic institutions and local government in order to move the region forward. A new organization, Joint Venture Silicon Valley, was established for this purpose and a public brainstorming process was initiated in the form of a series of open meetings focused on generating ideas for the future technological candidates. A venture capital approach was taken, with a few promising ideas, like computer networking, winnowed from a larger collection (Miller, 1997).

The innovation process folds back in on itself when one space becomes the basis for the development of another. For example, science parks created at a university as a mechanism to retain firms originated from that university, as well as provide an income stream to the region, could subsequently be replicated by other universities to assist the firm formation process and enhance links between local R&D units and university researchers. Stand-alone science parks were also established, primarily as a site for large corporate R&D units and branch R&D units of multi-national corporations. In recent years, science parks, like Stockholm's Kista, which have lost many of their original clients, have taken steps to renew themselves by expanding their knowledge space, founding entrepreneurial universities as a source of future start-ups.

9. Conclusions and Policy Implications: Exogenous and Endogenous Approaches to Regional Development

Since the 1990s, the development of regional innovation systems as foundations for regional growth has increasingly taken centre stage on the agenda of cities and regions seeking to revitalise their economies and improve their competitive advantage. In the context of increasing application of the "multi-level governance" and devolution of central powers to regional and local administrations, in parallel with an increasing role of European Union policies at national and regional level,
(Hooghe, 1996; Marks et al., 1996; Cooke et al., 2000), the "region" has gained growing recognition as the most appropriate scale to sustain innovation-based learning economies (e.g. Castells and Hall, 1994; Asheim and Isaksen, 1997; Storper, 1997; Cooke, 2001; Doloreux, 2002).

Regions have different strengths and weaknesses, and display a considerable diversity in innovation performance within countries. For example, innovation-intensive regions can be located in less innovative countries (e.g. Noord Brabant, a highly innovating region in an "innovation follower" country, the Netherlands, or the capital regions of Hungary and Slovakia, which have an innovation level at the EU average and are located in "catching-up countries" with an overall innovation performance well below average) (Hollanders, Tarantola and Loschky, 2009).

At the core of regional innovation policies has been the promotion of localized learning processes and capabilities to secure a competitive advantage of regions, by improving firm-specific competencies, specialized resources, skills, sub-contractor and supplier

relations and the sharing of common social and cultural values (Maskell and Malmberg, 1999; Cooke *et al.*, 2000; Tödtling and Kaufmann, 2001; Asheim and Gertler, 2004), enhancing interactions between different innovation stakeholders, such as firms, universities and research institutes, or between small start-up firms and larger (customer) firms (Cooke, 2001), and promoting the development of local comparative advantages linked to specific local resources (Maillat and Kébir, 2001).

In promoting localised learning processes, two basic approaches have been usually combined: an exogenous vision of attracting innovative high-tech firms to relocate in the region, as a variant of the traditional approach of attracting industrial branch plants, and an endogenous vision of creating an underlying science and arts base, as well as the mechanisms to support the formation of knowledge-based firms and creative industries.

Exogenous regional development strategies based on firm relocation/attraction originate in the neoclassical view that firms' decisions are responsive to small differences in input prices. This old strategy is predicated upon a microeconomic theory that stipulates that firms prefer locations that offer lower factor prices (Feldman and Francis, 2004). Consequently, cost reducing measures such as better locations, government programmes, etc. became important factors in location choices.

Endogenous regional development strategies recognise that other factors, such as skilled labour services and proximity to sources of knowledge and expertise, are much more important than cost reductions, especially for high-tech firms. Innovative start-ups and smaller firms, lacking the resources of their larger counterparts, are more dependent on resources in their local environments. Therefore, creating the infrastructure for knowledge-based firm formation and growth is the essence of an endogenous high-tech regional development strategy, which makes the success of the local innovative firms and the success of the region dependent on each other (Feldman and Francis, 2004).

In practice, endogenous and exogenous approaches exist in close relationship, but it is important to distinguish their precise roles in order to avoid the trap of mistaking effect for cause. For example, U.S. federal government research funding during the 2nd World War and in the post-war played an important role in the development of both Boston and Silicon Valley, acting as an exogenous factor that expanded upon an endogenous process of knowledge-based regional development that was well underway from the early 20th century in both regions. Another example of endogenous development intersecting with the exogenous factor are the large-scale research programmes in data mining funded by the Defence Advanced Research Projects Agency at Stanford and a few other universities. These research programmes provided the context for the development of the Google search algorithm that soon became the basis of a firm formation project in an area primed for the emergence of new technological candidates to renew the region.

Exogenous and endogenous strategies are also distinguishable by their originating base: the top-down for the former, and the bottom-up for the latter. Generally, the top-down model is based on the active role of external actors such as central governments, private banks, and transnational firms. Jobs, wealth and a larger local tax base are created by the injection of funds from outside the region. External investments as key inputs for regional development come in response to improved infrastructure and fiscal incentives provided by federal or state governments. They are often complemented by top-down

programmes of central governments that aim to promote technology and high-growth entrepreneurship through public and private partnerships, stimulate growth in a designated region and the development of high-tech centres or science and technology parks (Malecki, 1991).

This top-down approach has been widely criticized for being disconnected from the local region and based instead on key policy decisions by central governments, interests of external firms and loan criteria set by banks with external head offices (Parker, 2001). The bottom-up approach has been promoted as an alternative, which emphasizes high-tech entrepreneurship and local capacity building through better use of local capital resources, increased local control and greater equity (Blakely, 1989). However, the growing support for these bottom-up initiatives needs to be balanced with evaluations of their performance, given the difficulties in mobilizing sufficient resources locally (Filion, 1998; Parker, 2001). Oftentimes, the lack of local resources is redressed by an attraction strategy. The paradox is that an attraction strategy is most likely to be successful when a region already has a critical mass of activity in a particular field, and is most likely to fail when that is lacking. Under these difficult circumstances, the best use of resources may be an endogenous strategy. Even though it is a longer-term effort, it may have a better chance of success if a good topic is selected, building upon previous strengths or emerging knowledge and creative foci (Svensson, Klofsten and Etzkowitz, 2010).

Aiming to renew regions by encouraging relocation of innovative high-tech firms in the region may mistake the end result of the process of knowledge-based growth for the start, ignoring the long-term nature of endogenous development. For example, Stanford Science Park is the result of decades of encouraging firm formation from Stanford University, which eventually resulted in the serendipitous transformation of an ordinary industrial park into a new model for a science park closely linked to university research. In some cases, lacking the patience and/or resources to create the conditions to foster endogenous knowledge-based growth through firm formation, some regions seek a shortcut and subsidize the construction of attractive buildings in the hopes of luring high-tech firms. If they are not joining a thriving cluster, like pharmaceutical firms moving to northern New Jersey or Boston, the exogenous attempt of attracting firms from elsewhere may turn into a “cargo cult” fantasy if the firms are recruited to a locale where they will lack peers (Massey et. al, 1992). Moreover, prioritising the creation of local physical infrastructure takes resources away from developing human resources to strengthen the knowledge base of the region.

Sometimes the physical focus also includes a related human resources attraction strategy. However, when an aspiring region attracts external resources, such as research groups and centres, they must be integrated into local networks or, otherwise like a foot-loose branch plant, they will be subject to poaching by competitors. Also, offering research resources and better work conditions to attract distinguished investigators may appear to be a faster approach then developing young researchers. This tactic has its risks, for example, critics charged that some distinguished researchers that Singapore had attracted were focused on transferring knowledge back home and indeed were treating their institutes as an extension of their homeland research group (Science, 2008).

In recent years, an increasing number of regions have adopted a *university-centred, long-term endogenous entrepreneurial approach,* which creates "steeples of excellence" around emerging research themes with commercial potential. Frederick Terman, as Dean of Engineering and then Provost at Stanford University, exemplified this approach, attracting several researchers who interacted around common themes such as microwaves, that crossed the boundaries between electrical engineering and physics in the 30's and 40's, and steroid chemistry- an outlying but increasingly important field from the 1950's. These topics attracted significant research funds and were the basis for spinning off firms and making Stanford a leading research and entrepreneurial university that helped transform its region from an agricultural to a knowledge base over a half-century. Technical firms interacting with the university strengthened its teaching and research base and fed back human capital and new ideas into the firms in a dialectical fashion (Lecuyer, 2007). Government funding of engineering research with military utility in the early post-war, eagerly sought by Terman after witnessing the scale-up of MIT research in war-time projects, expanded the technical community within and outside the university.

A knowledge-based strategy thus replaces the traditional strategy of local economic development, often single-mindedly focused on relocation of branch plants into the region. This exogenous strategy of attracting firms from elsewhere, often subsidiaries of large multi-nationals, based on marketing existing assets, such as trained workforce, good infrastructure and living conditions, in addition to subsidies to support plant renovation and/or training, is no longer viable. On the one hand, the pool of plants that can be attracted, no matter how good the offer, is reduced by the significant decline of many manufacturing industries in highly developed economies, and on the other, the competition in the marketplace increasingly relies on local knowledge assets that often have to be built or reinforced. This calls for an endogenous strategy aimed at enhancing knowledge generation and commercialisation capabilities and inventing new innovation formats, along with a revised exogenous strategy.

The process of developing a university-centred endogenous strategy for regional development is a complex, long-term phenomenon involving the Triple Helix actors of University, Industry and Government to different extents over time. We have analyzed the dynamics of this process using the conceptual framework of *Triple Helix Spheres and Spaces*, to capture not only the systemic nature of the interaction among the university-industry-government institutional spheres, but also the time dimension of this interaction, in its synchronic and diachronic aspects. The Triple Helix model, through its constellation of actors and relationships is a conducive framework for an endogenous strategy.

We have argued that the transition from one stage of an endogenous strategy to another is the result of the interplay between three Triple Helix "Spaces" that we call Knowledge, Consensus and Innovation. We compared and contrasted the main features of exogenous and endogenous strategies for knowledge-based economic development and their originating base in top-down and bottom-up policy approaches. We showed that a non-linear passage from one space to another takes place as regions regenerate themselves. Conversely, we suggested that inability to deploy resources to realize a coherent strategy and inadequate measures dissipate after repeated failure to achieve goals that may be unrealistic. Success has many parents; failure hardly finds a presence in the literature of regional innovation, despite the learning opportunities it offers for

aspiring regions, as well as individual entrepreneurs for whom its positive effects have been noted.

The Spaces are an attempt to integrate the dynamics of the institutional and communicative Triple Helix regimes into a "red thread" framework that could guide policy and practice in the process of creating and consolidating knowledge-based regional innovation systems. Understanding the dynamics of the spaces in the "tila" sense of passage from one space to another can be helpful in constructing such a strategy. From a relatively few instances like Boston's Route 128 that was considered to be unique thirty years ago (Dorfman, 1983), virtually all regions world-wide attempt to enhance their development chances in the early 21st century through initiatives to promote knowledge-based economic and social development.

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