Triple Helix Systems: An Analytical Framework for Innovation Policy and Practice in the Knowledge Society

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Abstract

This paper introduces the concept of Triple Helix systems as an analytical construct that systematizes the key features of university-industry-government (Triple Helix) interactions into an 'innovation system' format defined according to systems theory as a set of components, relationships and functions. This conceptual framework offers a broad perspective for understanding the sources and development paths of innovation, and can be an attractive paradigm for regions that aim to enhance their knowledge base and create "steeples of excellence" around research themes with commercial potential and innovative firms. Triple Helix systems delineate how new regimes appear through creative reconstruction and provide new insights into innovation dynamics.

Key words: Triple Helix Systems; Knowledge Space; Innovation Space; Consensus Space; university-industry-government interaction; innovation systems; regional innovation strategies.

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Introduction

Recent decades have seen a shift from an earlier focus on innovation sources confined to a single institutional sphere, whether product development in industry, policy-making in government or the creation and dissemination of knowledge in academia, to the interaction among these three spheres as the source of new innovative organisational designs and social interactions. This shift entails not only various mechanisms of institutional restructuring of the sources and development path of innovation, but also a rethinking of our main models for conceptualizing innovation, including innovation systems (national, regional, sectoral, technological, etc.) and the Triple Helix. In this paper, we introduce the Triple Helix systems as a novel analytical concept that systematizes the key features of university-industry-government interactions, so far loosely addressed as a 'metaphor' or a 'framework', into an 'innovation system' format that highlights the key new sources of novelty and the dynamics of their interaction.

We define Triple Helix systems according to the systems theory (Carlsson and Stankiewicz, 1991; Carlsson et al. 2002; Edquist 2005; Bergek et al. 2005) as a set of: **(i) components** (the institutional spheres of University, Industry and Government, with a wide array of actors; **(ii) relationships between components** *(*collaboration and conflict moderation, collaborative leadership, substitution and networking); and **(iii) functions**, described as processes taking place in what we label the 'Knowledge, Innovation and Consensus Spaces'. This hybrid theoretical approach provides a relevant base for innovation strategies and resolves some of the key flaws in previous innovation systems approaches, such as diffuseness and conceptual heterogeneity, strong focus on institutions (especially firm-centrism and bias on R&D-intensive, high tech industries) and low visibility of individual innovators, difficulty to draw system boundaries (Malerba, 2002; Edquist, 2005; Godin, 2007). Triple Helix systems provide a fine-grained view of innovation actors, relationships between them and knowledge flows within the system, in a vision of a dynamic, boundary-spanning diachronic transition between the Knowledge, Innovation and Consensus Spaces. Triple Helix systems accommodate both institutional and individual roles in innovation, and explain variations in the innovative performance in relation to the existence and development stage of the three spaces, the strength of relationships between them and their capacity to integrate various regional development strategies. Transcending sectoral or technology boundaries, Triple Helix systems focus on boundary permeability among the institutional spheres as an important source of organisational creativity, encouraging individuals to move within and

between the spheres and engage in recombination of elements to create new types of organizations. These effects are most relevant at the regional level, aiming to combine local resources for realising joint objectives and new institutional formats in any of the Knowledge, Innovation and Consensus spaces. From this analytical framework, empirical guidelines for policy-makers, university and business managers can be derived, in order to strengthen the collaboration among Triple Helix actors and enhance regional development.

The concept of the Triple Helix of University-Industry-Government relationships developed in the 1990s by Etzkowitz (1993) and Etzkowitz and Leydesdorff (1995), encompassing elements of precursor works by Lowe (1982) and Sábato and Mackenzi (1982), interprets the shift from a dominating industry-government dyad in the Industrial Society to a growing triadic relationship between university-industry-government in the Knowledge Society. Through subsequent development (e.g. Etzkowitz and Leydesdorff, 1998, 2000; Leydesdorff, 2006) the concept has grown into a conceptual framework for exploring the complex dynamics of the Knowledge Society and for informing policy-makers at national, regional and international level in the design of new innovation and development strategies. For example, the Swedish Governmental Agency for Innovation Systems VINNOVA devotes an important part of its activities to stimulating the cooperation between firms, universities, research institutes and other Swedish innovation actors - a mission adopted in the early 2000s, shortly after the agency's inception, and achieved through, among others, the VINN Excellence Centres and the VINNVÄXT Programme. Brazil's 2004 Innovation Law incentivizes the interaction between firms, public universities and research centres, allows grants to innovative firms, the set-up of private firms' incubation facilities in public universities and the shared use of university infrastructure. University-industry-government cooperation has a central role also in European Union (EU) innovation policies, such as the *Innovation Union* flagship initiative of the *Europe 2020* Strategy, and is perceived as a solution to the "innovation emergency" that Europe now faces (European Commission, 2011; Geoghegan-Quinn, 2012). The European Regional Development Fund and the European Social Fund allocate significant funding for these objectives and several EU initiatives have been designed for this purpose[1].

[1] For example, the EU Business Forum, established in 2008, the 2011 pilot action "Knowledge Alliances", which includes partnerships between businesses, higher education and training institutions to develop educational material, the European Institute of Technology, which supports the full integration of the Knowledge Triangle (education, research and the innovation) through the so-called 'Knowledge and Innovation Communities'.

A significant body of Triple Helix theoretical and empirical research has been developed over the last two decades or so along two main complementary perspectives: (i) a *(neo)institutional one,* which examines various Triple Helix configurations and inducing mechanisms in national and regional contexts (e.g. Etzkowitz, 2003, 2008; Benner and Sandström, 2000; Inzelt, 2004; Etzkowitz, Mello and Almeida, 2005; Boardman and Gray, 2010; Lawton Smith and Bagchi-Sen, 2010; Saad and Zawdie, 2011); and (ii) *a neo(evolutionary) one,* which looks at university, industry and government as co-evolving sub-sets of social systems that interact through market selections, innovative dynamics and network controls, communicate through specific codes and institutionally adapt by negotiations and translations at their interfaces (Leydesdorff 1994; 1997, 2000; 2008; Etzkowitz and Leydesdorff, 1995; Leydesdorff and Etzkowitz,1998). The systemic nature of the Triple Helix interactions is an implicit dimension of both perspectives, and reflects to a large extent their common vision of Triple Helix interactions as manifestations of social systems, characterised by action[2] (Parsons, 1951; Parsons and Shils, 1951; Parsons and Smelser, 1956) and communication[3] (Luhmann, 1975; 1984; Shannon, 1948). However, an explicit analytical framework for conceptualizing the systemic nature of Triple Helix interactions has not been provided so far. The Triple Helix systems concept that we introduce in this paper aims to fill this gap and provide the analytical foundation for a new vision of university-industry-government interactions.

The paper is organized as follows: Section 1 introduces the conceptual framework of Triple Helix systems and relates it to relevant literature. Sections 2-4 present the structural elements of Triple Helix systems: components, relationships between components and functions, defined as specific activities to the Knowledge, Innovation and Consensus Spaces. Section 5 discusses the formation and functioning of the spaces. Section 6 elaborates on the relevance of Triple Helix systems for regional innovation strategies, based on their capacity to integrate both endogenous and exogenous regional innovation strategies. Section 7 provides a

[2] Parsons sees a social system as part of a social action system that comprises the economy (social adaptation to its action and non-action environmental systems), the polity (collective goal attainment), the societal community (the integration of its diverse social components) and the fiduciary system (processes that function to reproduce historical culture in its "direct" social embeddedness).

[3] Luhmann sees social systems as systems of communication, which operate by processing ‘meaning’ and constantly re-creating themselves through their communication, subject to what is considered meaningful and what is not, in a process of self-regeneration called autopoiesis.

comparative analysis of Triple Helix systems and other innovation systems approaches, highlighting the way the former approach resolves some of the flaws of the latter. Section 8 concludes the paper with a summary of findings and directions for further research.

1. TRIPLE HELIX SYSTEMS: CONCEPTUAL FRAMEWORK

The Triple Helix thesis is that the potential for innovation and economic development in a Knowledge Society lies in a more prominent role for the university and in the hybridisation of elements from university, industry and government to generate new institutional and social formats for the production, transfer and application of knowledge. This vision encompasses not only the creative destruction that appears as a natural innovation dynamics (Schumpeter, 1942), but also the creative renewal that arises within each of the three institutional spheres of university, industry and government, as well as at their intersections.

The enhanced role of the university in the Knowledge Society arises from several specific developments. First, *the recent addition of the university 'third mission' - involvement in socio-economic development*, next to the traditional academic missions of teaching and research, is the most notable, being compared to a "second academic revolution" (Etzkowitz, 2003). This 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). *Secondly, the university's continuous capacity to provide students with new ideas, skills and entrepreneurial talent* has become a major asset in the Knowledge Society. Students are not only the new generations of professionals in various scientific disciplines, business, culture etc., but they can also be trained and encouraged to become entrepreneurs and firm founders, contributing to economic growth and job creation (see, for example StartX, Stanford's student start-up accelerator, which in less than a year

trained 90 founders and 27 companies[4], or the Team Academy - the Entrepreneurship Centre of Excellence of JAMK University of Applied Sciences in Jyväskylä, Finland, where students run their own cooperative businesses based on real-life projects[5]). Universities are also extending their capabilities of educating individuals to educating organizations, through entrepreneurship and incubation programmes and new training modules at venues such as inter-disciplinary centres, science parks, academic spin-offs, incubators (Etzkowitz, 2008; Almeida, Mello and Etzkowitz, 2012). *Thirdly, universities' capacity to generate technology has changed their position,* from a traditional source of human resources and knowledge to a new source of technology generation and transfer, with ever increasing internal organizational capabilities to produce and formally transfer technologies rather than relying solely on informal ties.

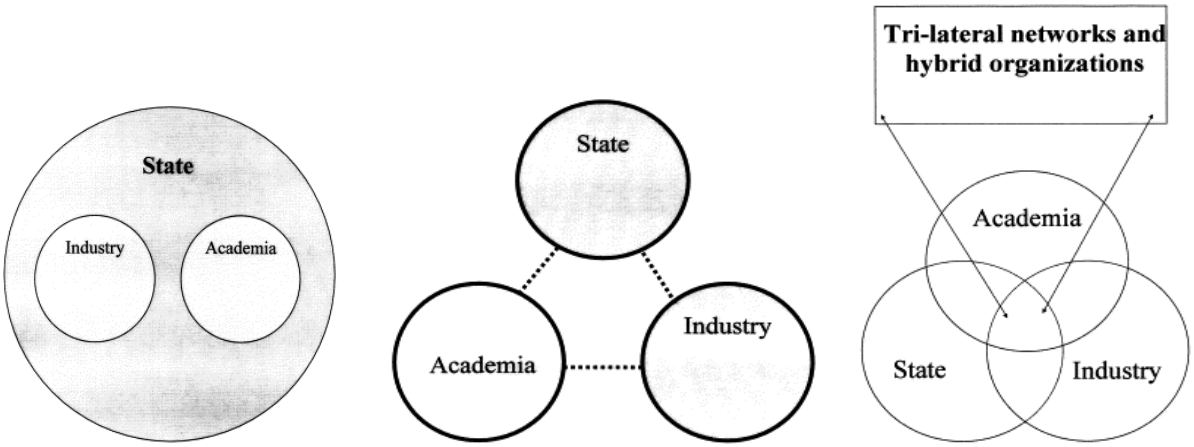
A substantive body of Triple Helix literature has been developed, consisting of two main complementary perspectives:

(i) A (neo)institutional perspective (e.g. Etzkowitz, 2003, 2008; Etzkowitz and Leydesdorff, 1996, 1999, 2000)) encompasses case studies and comparative historical analyses that explore different configurations arising from the positioning of the university, industry and government institutional spheres relative to each other and their movement and reorientation, with one as a gravitational centre around which the others rotate (Fig.1). For instance, in a *statist regime*, government plays the lead role, driving academia and industry, but also limiting their capacity to initiate and develop innovative transformations (e.g. in Russia, China, some Latin American and Eastern Europe countries). In a *laissez-faire regime*, characterised by a limited state intervention in the economy (e.g. the US, some Western Europe countries), industry is the driving force, with the other two spheres as ancillary support structures and limited roles in innovation: university acting mainly as a provider of skilled human capital, and government mainly as a regulator of social and economic mechanisms. In the transition to a Knowledge Society, a *balanced regime* is emerging, whereby university and other knowledge institutions play an increasing role, acting in partnership with industry and government and even taking the lead in joint initiatives, (Etzkowitz, 2008). The balanced model offers the most important insights, as the best environments for innovation are created at the intersections of the spheres. This is where creative synergies emerge and set in motion a process of "innovation in innovation", create

[4] See http://startx.stanford.edu/
[5] See http://www.tiimiakatemia.fi/en/

new venues for interaction and new organisational formats, as individual and organisational actors not only perform their own role, but also "take the role of the other" when the other is weak or under-performing (Etzkowitz and Leydesdorff 2000; Etzkowitz, 2003). Through this creative process, the relationships among the institutional spheres of university, industry and government are continuously reshaped in "an endless transition" to enhance innovation (Etzkowitz and Leydesdorff, 1998), bringing forth new technologies, new firms and new types of relationships in a sustained systemic effort.

Figure 1 – Triple Helix configurations



(1) A 'statist' model (2) A 'laissez-faire' model (3) A 'balanced' Triple Helix model

Source: Etzkowitz and Leydesdorff (2000)

(ii) A (neo) evolutionary perspective, inspired by the theory of social systems of communication (Luhmann, 1975, 1984) and mathematical theory of communication (Shannon, 1948), which sees the University, Industry and Government as co-evolving sub-sets of social systems. Interaction between them occurs through an overlay of recursive networks and organizations which reshape their institutional arrangements through reflexive sub-dynamics (e.g. markets and technological innovations) (e.g. Leydesdorff, 1996, 1997, 2000, 2006, 2008; Etzkowitz and Leydesdorff, 1995; Leydesdorff and Meyer, 2006; Dolfsma and Leydesdorff, 2009). These forms of interaction are part of two processes of communication and differentiation*: a functional* one, between science and markets, and *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, *internal 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). The institutional spheres are also seen as *selection environments*, and the institutional communications between them act as *selection mechanisms*, which may generate new innovation environments and ensure thus the 'regeneration' of the system (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000). The activities of the Triple Helix actors are measured in terms of probabilistic entropy, 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).

The systemic nature of the Triple Helix interactions is an underlying dimension of both perspectives described above, originating from their common vision of Triple Helix interactions as manifestations of social systems (Parsons, 1951; Parsons and Shils, 1951; Parsons and Smelser, 1956; Luhmann, 1975; 1984). However, an explicit analytical framework for conceptualizing Triple Helix systems has not been provided so far. In this paper, we introduce the concept of **Triple Helix systems** as an analytical construct defined from the perspective of systems theory as a set of**:**

(i) **Components***:* the institutional spheres of University, Industry and Government, each encompassing a wide-ranging set of actors;

(ii) **Relationships between components:** collaboration and conflict moderation, collaborative leadership, substitution and networking;

(iii) **Functions:** described as a set of activities specific to the "Triple Helix Spaces": the Knowledge, Innovation and Consensus Spaces.

This perspective builds upon the *structure/process conceptual construction of innovation systems* (Bergek et al. 2008) that complements the structure of innovation systems with a process dimension, which focuses on the dynamics and achievements of the system rather than on its structural components and separates structure from content. The three structural elements of Triple Helix systems, their formation, functioning and relevance for policy-making are discussed in detail in the following sections.

2. COMPONENTS OF TRIPLE HELIX SYSTEMS

Much of the Triple Helix literature focuses on the institutional spheres of university, industry and government as holistic, 'block' entities, without going deeper to the level of specific actors within each sphere, which obscures some specific ways in which the actors' institutional identities, missions, objectives, needs, etc. influence the interaction dynamics. On the one hand, this simplified perspective can sometimes be beneficial, especially in contexts where one or more of the helices are still in the early development phases and the culture of collaboration is weak, as it may increase the applicability and suitability of the Triple Helix model to local policy and practice. The simplicity of the model is appealing to policy-makers and may help mobilize local innovation agents, bring legitimacy to policy efforts and improve coherence between different policy strands involved in innovation (Rodrigues and Melo, 2010). On the other hand, in more advanced contexts, where innovation stakeholders are more mature and have attained more complex forms of interaction, the simplified perspective described above is no longer sufficient. A more internally differentiated approach of the Triple Helix actors is necessary to understand their behaviour and specific contributions to a complex division of labour in the production and use of knowledge for innovation (see the analysis of MIT in the 1930s in Etzkowitz, 2002).

In defining the components of Triple Helix systems, three important distinctions are made: **a) between R&D and non-R&D innovators;** b) **between "single-sphere" and "multi-sphere" (hybrid) institutions;** and c) **between individuals and institutions.**

a) R&D and non-R&D innovators: this distinction, based on the performance of in-house (intramural) R&D[6], arises from the recognition of the fact that R&D is not the only driver of innovation (Kline and Rosenberg, 1986; Cohen et al. 1987; Galende and Suarez, 1999; Von Tunzelmann and Acha, 2005; Jensen et al. 2007; Hirsch-Kreinsen, 2008; Heidenreich, 2009). Other activities like technology adoption, incremental changes, imitation, and combining existing knowledge in new ways can also increase organizational innovative capacity (Arundel et al, 2008). This distinction reflects the permanent, albeit not always harmonious coexistence of tacit and codified knowledge and is translated in different modes of learning and innovation, e.g. the Science, Technology and Innovation (STI) mode, based on the production and use of codified scientific and technical knowledge, and the

[6] R&D innovators perform in-house (intramural) R&D, while non-R&D innovators do not.

Doing, Using and Interacting (DUI) mode, based on informal processes of learning and experience-based know-how (Jensen et al. 2007).

- **R&D innovators** can be found in each of the University, Industry and Government institutional spheres, as well as beyond that, in the non-profit sector (e.g. charities, foundations, professional/trade associations, service organizations, not-for-profit corporations, trusts, etc.). In universities, key R&D performers are the academic research groups and interdisciplinary research centres; in the business sector, the company R&D divisions or departments; in the government sector, the public research organizations, mission-oriented research laboratories, etc. One can also mention here a functional equivalent of R&D activities in arts and design fields, or more broadly in the creative industries, which generates artistic and cultural activities similarly to scientific R&D, but with their own distinct discovery, methodologies, validation and dissemination procedures[7].
- **Non-R&D innovators** are most often associated with the Industry institutional sphere, as company actors involved in non-R&D activities, like design, production, marketing, sales, acquisition of technology or machinery produced by other companies or research organisations, customization or modification of products and processes obtained from elsewhere, personnel training and competence-building, interaction with users, acquisition of patents and licenses, consultancy services, etc. On a broader scale, non-R&D innovation is also present in the creation and change of organisations, technology transfer, incubation activities, financing, negotiation, etc. However, such activities are not confined to the Industry borders and can also be found in various forms in the Government and University spheres, as well as in the non-profit sector.

(b) "Single-sphere" and "multi-sphere" (hybrid) institutions:

- **"Single-sphere" institutions** are traditionally delineated within the boundaries of a single institutional sphere, be it University or Industry or Government (e.g. education

[7] For example, the members of *The Kitchen* in New York City's Soho District invent new forms of conceptual art, new artistic formats and modes of performance that inspire other artists and are disseminated through international performance tours. Although *The Kitchen* members do not explicitly view themselves from an innovation perspective, they instigate an innovation process in their domain. The fashion department of the Antwerp Academy in Belgium encourages students to create and explore innovative forms, original treatments of materials, stimulate experimentation and improvisation, in a way similar to the teaching laboratory. The Costume Institute at the Metropolitan Museum of Art in New York is the cultural memory of the industry that is regularly utilised as a source of ideas in the form of historical styles that may be reinterpreted in new ways with new materials or hybridised into new formats.

institutions, business firms, government agencies). Their functioning, specific to a *laissez-faire* regime (see Fig. 1 above), is characterized by high specialization and work centralization, limited mobility of workers, rigid and inertial institutional boundaries, low interaction with entities of another institutional sphere, etc.

- **"Multi-sphere" (hybrid) institutions** operate at the intersection of the University, Industry and Government institutional spheres and synthesize in their institutional design elements of each sphere, in a *balanced* Triple Helix regime (see Fig.1 above). Technology transfer offices in universities, firms and government research labs, industrial liaison offices, business support institutions (science parks, business and technology incubators), financial support institutions (public and private venture capital firms, angel networks, seed capital funds, etc.) can be included in this category. They have smaller-scale hierarchies, with fewer layers and more decentralized decision-making, in order to increase flexibility and responsiveness to changing market demands. Also, institutional boundaries are more permeable (Etzkowitz, 2012) as the single institutional spheres of University, Industry and Government become more laterally diversified and increase collaboration to improve work effectiveness. Subsequently, boundaries between the job categories involved in these hybrid structures become looser and require greater task- and knowledge-sharing.

The distinction between "single sphere" and "multi-sphere" (hybrid) institutions arises from the transition from the Industrial to the Knowledge Society, manifested through increasing communication and interconnectivity between people and institutions, mobility of people and financial capital, delocalisation and globalisation of production sites, labour and social relationships, etc. Elements like generation and internalization of new skills and abilities required for integration into dynamic work environments, access to both information and knowledge, uneven development of scientific and technological (including organisational) knowledge across different sectors of activity, approach to intellectual property rights and the privatisation of knowledge, as well as the approach of trust, memory and the fragmentation of knowledge (David and Foray, 2003) make an important difference between the single- and multi-sphere (hybrid) institutions.

c) Individual and institutional innovators. Innovation studies, often focused on teams, institutions and organizations at country or regional levels, have a low visibility of the

individual innovator. Triple Helix systems acknowledge the importance of individual innovators and entrepreneurs and their role in initiating and consolidating institutional processes. Concepts like the "innovation organizer" and the "entrepreneurial scientist" provide a phenomenology of behavioural types (Schutz, 1959), highlighting the ways in which individual and institutional innovation and entrepreneurship initiate and reinforce each other.

- **The 'Innovation Organizer"** is defined as a person that typically occupies a key institutional position, enunciates a vision for knowledge-based development and has sufficient respect to exercise convening power to bring the leadership of the institutional spheres together. The Innovation Organizer coordinates a mix of top-down and bottom-up processes that ensure agreement and build a platform where innovation stakeholders 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 for improving the conditions for knowledge-based development. For example, in the 1930's New England, MIT's President Compton was the Innovation Organizer who played a key role in getting support for a new model of knowledge-based economic development relying heavily on university-originated technologies. In the mid 1990's New York, the Head of the New York Federal Reserve Bank initially took the lead in calling for high-tech development as an alternative to finance as the engine of New York's economy. In 2011, New York's Mayor Bloomberg re-took the Innovation Organizer role with an initiative to attract leading technological universities to the city to fill the gap in the region's innovation environment[8]. The Innovation Organizer role can be extended from an individual to one or indeed a consortium of institutions, as in the case of Birmingham University's consortium of Triple Helix actors who projected the post-Rover, post-automotive future of the West-Midlands, UK. The consortium envisioned the development of the region as a future technology corridor including a biomedical complex based on area research, steered by boundary-spanning collaborative leadership that was capable of transcending entrenched local interests (Gibney, Copeland and Murie, 2009).
- **The 'entrepreneurial scientist' concept** combines academic and business elements. The entrepreneurial scientist simultaneously attends to advancing the frontiers of knowledge and mining its practical and commercial results for industrial and financial

[8] See http://online.wsj.com/article/SB10001424052970204879004577107190097493490.html.

returns. The underlying foundation of this development is the polyvalent nature of knowledge, which is at the same time theoretical and practical, publishable and patentable. Different academic entrepreneurial styles and degrees of involvement can be distinguished, including a direct interest in the formation of a spin-off firm and in taking a leading role in this process, or handing over these results to a technology transfer office for disposition; interest in playing a supporting role, typically as member of a Scientific Advisory Board; no interest in entrepreneurship, but in firm-formation as useful source for developing technology needed to advance basic research goals. Communities of complementary entrepreneurial individuals are particularly visible in high-tech entrepreneurship, which is virtually always a collective phenomenon. A new high-tech firm typically takes off with the support of persons with technical and business expertise backed by an experienced entrepreneur, constituting together the "collective entrepreneur", as only rarely does a single individual embody all of these required elements. However, in the US a strong ideology of individual entrepreneurship usually suppresses the contributions of collaborators and pushes a single individual to the forefront[9] (Freiberger and Swaine 2000). In Sweden, by contrast, collective entrepreneurship is openly accepted, as individuals are culturally inhibited from attempting an entrepreneurial act unless backed up by a group.

3. RELATIONSHIPS BETWEEN COMPONENTS OF TRIPLE HELIX SYSTEMS

Interaction between the components of Triple Helix systems can take different forms, reflecting the evolutionary social and economic mechanisms that induce change in Triple Helix regimes:

a) Collaboration and conflict moderation is a specific form of interaction in triadic entities, which have a higher potential for turning tension and conflict of interest into convergence and confluence of interest, compared to dyadic relationships, which are more subject to collapse into oppositional modes (Simmel, [1922] 1955). This capacity to transform tension and conflict of interest into converging interests around common objectives and win-win situations is all the more important as the very nature of conflicts and tensions is

[9] For example, in the creation of the Apple origin myth, Steve Jobs moved to the foreground, while Steve Wozniak, the technical collaborator, and Mark Makula, the experienced semiconductor executive, who gave the original duo credibility with suppliers and financers, were elided (Freiberger and Swaine 2000).

changing in the Knowledge Society, in line with the changing nature of work, workplace and organizations (Heerwagen, Kelly and Kampschroer, 2010). As the knowledge content of many jobs is increasing, their attachment to particular companies is reducing and moving towards a vision of work that is defined as a life-long process of education and cognitive development rather than a company career (Spittle, 2010).

b) Collaborative leadership, in the sense of "a purposeful relationship in which all parties strategically chose to cooperate in order to accomplish a shared outcome" *(*Rubin, 2009) is an integral part of the capacity of collaboration and conflict moderation. Individual or institutional 'Innovation Organizers' as described above, play an important role in this type of interaction.

c) Substitution: this type of interaction arises when institutional spheres fill gaps that emerge when another sphere is weak. **Substitution between spheres** is exemplified by government agencies taking up, in addition to their traditional function of regulation and control, investment and provision of public venture capital, which is a traditional task for the Industry sphere (e.g. Gebhardt, 2012). Similarly, universities, in addition to their teaching and research activities, often 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 can also take the role of the university in developing training and research, often at the same high level as universities. Substitution between spheres can also be observed at a higher level, in countries with no or weak regional governments, where there may not be a governmental actor available to take the lead in promoting innovation developments, but other actors, such as universities and firms, may come forward to set forth a future achievable objective (playing an Innovation Organizer role, as described above). **Substitution within spheres** is also possible, for example when vocational training institutions take the lead over universities in engaging into joint initiatives with local firms (especially with low-tech, low/non-R&D small firms) that prefer the more practical, shorter-term oriented opportunities of the vocational training institutions to the more complex, long-term programmes of the university (Ranga et al. 2008).

d) Networking into formal and informal structures at national, regional and international level is another major form of interaction among Triple Helix system components. The aggregation may be easier or more difficult to identify, depending on the network's age,

scope, membership, activities and visibility in the public domain (e.g. the Association of University Technology Managers AUTM, the European Technology Platforms and Joint Technology Initiatives, to mention just a few examples[10]). Networks are not a specific phenomenon to Triple Helix interactions, like the other relationships described above, but are widely found in this type of interactions too. They have been increasingly described over the last decades under diverse labels, e.g. *'techno-economic networks"* (Callon, 1992), *'networks of innovators'* (Cusumano and Elenkov, 1994; DeBresson and Amesse, 1991; Freeman, 1991), partly in response to the limitations of hierarchies and markets, as an organizational form much better suited to the changing complexities of contemporary society -"*neither market nor hierarchy"* (e.g. Powell, 1990). More flexible than hierarchies, more invested in the public good than markets and more effective in responding to changing conditions than either hierarchies or markets, networks have been seen as 'the middle way' between the loose coupling of markets and the tight relationships of hierarchies. Research networks in academia have become comparable to a 'joint venture', whose stability appears to be of critical importance socially, politically and economically, in order to generate a particular division of labour among the participants (David, Foray and Steinmueller, 1999). Networking reflects the growing non-linearity and interactivity of innovation processes (Kaufmann and Tödtling, 2001) and provides several benefits[11] (Steinmueller, 1994).

4. FUNCTIONS OF TRIPLE HELIX SYSTEMS: THE KNOWLEDGE, INNOVATION AND CONSENSUS SPACES

The functions of Triple Helix systems are defined as a set of processes specific to the **Triple Helix Spaces - Knowledge, Innovation and Consensus**:

a) The Knowledge Space is the set of knowledge generation, diffusion and use activities of the Triple Helix components discussed in Section 2 above. The construction of this space is an essential step in the transition to a Knowledge Society and has the ultimate

[10] The European Technology Platforms (ETPs) are industry-led multinational networks (36 ETPs in 2011) that bring together various stakeholders to define a common vision and implement a medium- to long-term Strategic Research Agenda in key industrial areas for Europe's competitiveness and economic growth (http://cordis.europa.eu/technology-platforms/). The ETPs have provided major input to European research programmes such as FP7, and some have been involved in the establishment of the Joint Technology Initiatives (JTIs), a form of long-term public-private partnerships that combine private sector investment and/or national and European public funding (five JTIs in 2011) (http://cordis.europa.eu/fp7/jtis/).

[11] For example, increasing network value with higher number of participants, reduction of research projects overlapping through network centralisation, complementary investments for information dissemination that may lead to economic benefits and easier access to information flows within the network by governments and firms, increasing their choices about specialisation, co-operation and competition (Steinmueller, 1994).

purpose to create a 'critical mass' of knowledge resources to strengthen the local, regional and national knowledge base, avoid fragmentation and reduce duplication of research efforts. To this end, knowledge resources are aggregated locally within a region, nationally across regions or trans-nationally (e.g. European Commission initiatives to consolidate the European Research Area) through a wide range of mechanisms, exemplified below, from dispersal or relocation of existing resources, to creation of new ones through institution formation, physical and virtual networking:

- *Dispersal of some national public research organisations from the capital to less research-intensive regions.* This was the case of government research labs moved from Mexico City to other regions of Mexico after the mid-1980s earthquake, with a double rationale: to protect them from a new earthquake, but also to provide research capacity to regions where that had heretofore been lacking and address the problems of the locality (Casas, Gortari and Santos, 2000). This policy was eventually broadened from a dispersal of research resources to an explicit knowledge-based regional development strategy, with more research institutes being transferred from the capital to other regions to strengthen their knowledge base.
- *Relocation and aggregation of existing research resources* - in North Carolina's Research Triangle, the North Carolina state used its political clout to induce the relocation of federal government labs from outside the state to the Research Triangle Park, where they were used as an attractor of corporate labs, within what became an initial framework for high-tech development strategy (Hamilton, 1966).
- *Attraction of leading researchers through the foundation of a science-based university*, as in San Diego, where a new branch of 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 called for the founding of this campus. The transformation of San Diego from a naval base and military retirement community to a knowledge-based conurbation followed. The strategy of the University of California San Diego campus was replicated by the Merced campus, which has recently been established as an "entrepreneurial university" to promote high-tech development in an agricultural region. The strategy aimed to create and then leverage location-specific knowledge assets to induce new investment and create new value.

- *Creation of new university resources to support the development of new industries or raise the existing ones to a higher level.* For example, the State University of Rio de Janeiro in Friburgo created a new campus providing an IT-oriented PhD programme to supply high-level knowledge inputs to a neighbouring declining industrial region, rather than simply training support personnel for existing firms as it might have happened in an undergraduate campus. In Norkopping, Sweden, in the wake of deindustrialization, a Council representing the city region's business and political leadership was established, and decided to create a university campus with advanced academic research groups in order to revive paper industry - one of the local traditional industries (Svensson, Klofsten and Etzkowitz, 2011).
- *Virtual congregation of geographically dispersed groups from university and industry around common research themes, with government support,* such as the Canadian Networks of Centres of Excellence (NCE). Large government sponsorship originally motivated widely dispersed academic and firm research units to work together to prepare funding applications, typically dividing up the funds to extend existing local projects, with a suitable overlay of collaborative rhetoric. The interaction and discussion necessary to prepare a proposal generated new research ideas and genuine intellectual collaborations spanning geographical and organizational boundaries.
- *Networking of existing knowledge-based organisations and creation of new ones through collaboration among existing players, in order to become internationally competitive*. This strategy is exemplified in Sweden by the founding of the Stockholm School of Entrepreneurship as a joint initiative of Stockholm University, Royal Institute of Technology (KTH), and more recently also including the Royal Art College. The Oresund project linking southern Sweden (Skane) and Copenhagen included the creation of Oresund University, an organisation that encourages collaboration and joint projects between universities on both sides of the strait that previously divided this cross-border region. Karolinska Institute initiated a university-building strategy of incorporating a series of small schools in the biological sciences, nursing and other loosely related field scattered across Sweden and even across the Norwegian border in order to create a greater "critical mass" of research, training and commercialization activities.
- *Re-organization of research funding from a linear to an interactive model.* Sweden has transformed its research funding system by shifting the emphasis from funding research as an end in itself, or for military or other specific purposes, to encouraging

university, industry and government institutional spheres to work more closely together to promote innovation. In the early 1990's a group of foundations were created to fill gaps in the country's innovation funding system. They became a new actor in a system that had been heretofore dominated by Research Councils, most of which were oriented to the older universities and traditional academic disciplines. The foundations changed a rigid innovation system both by providing alternative sources of funds and by their willingness to seek out new research providers, beyond creating a diversity of funding sources in a research funding system that had become out of phase with the country's innovation needs.

b) The Innovation Space consists of the activities undertaken particularly by the 'multi-sphere' (hybrid) organizations and entrepreneurial individual and institutions discussed in Section 2 above, having as ultimate purpose the creation and development of intellectual and entrepreneurial potential, attraction of talent and innovative firms from elsewhere, and building a competitive advantage for the region and the country. These joint institutional and individual innovation efforts that come together in a form of "public" entrepreneurship go well beyond firm formation and provide the energy and focus for a variety of institution-formation projects (Schumpeter, 1951; Etzkowitz and Schaflander, 1969). The new institutional formats thus emerged depend on the strengths and weaknesses of the actors involved, their motivation, aptitudes, location, entrepreneurial capacities, institutional support for new firm formation, level of local economic and technological performance (Mason and Harrison, 1992; Thwaites and Wynarczyk, 1996; Lee and Peterson, 2000). The innovative potential of hybrid organizations can be strengthened through entrepreneurial training programmes and business plan competitions that are now are increasingly implemented worldwide (Morris, 1998) and are a key element for economic and social development in a national, regional or local innovation environment. The creation of an Innovation Space can take place through various mechanisms, including:

- *Creation of a university in a region without higher education capacity*, as a means of raising the technological level of existing clusters or as a source of new ones. MIT is the classic instance of a university founded to raise the technological level of existing clusters. It was founded in 1862 to support the Boston textile, leather and mechanical industries by infusing them with new ideas from science-based technology. Limited resources at the time precluded much effort in this direction apart from providing

industry with trained engineers. By the time MIT developed research capabilities in the early 20th century, the industries it was intended to support had largely moved from the region to be close to raw materials, lines of distribution and access to inexpensive labour. It was in this context that MIT moved to the next stage of regional development, from supporting existing industries to playing a role in the creation of new industries through firm formation from its research programmes and by playing a collaborative role with business and government in creating a venture capital industry to support new firm formation and growth (Etzkowitz, 2002). In the 1950's, the regional leadership of San Diego deployed this explicit model of a science-based entrepreneurial university as a strategy for creation of a new science-based industry in a region that was heretofore known as a naval base and retirement community. With a charter for a new campus of the University of California, leading scientists were recruited in emerging area of "polyvalent knowledge," with both theoretical and practical potential, as a long-term strategy to foster industrial development. A few decades later, by assiduously pursuing the strategy of developing a critical mass of research groups and institutes in bio-technology related fields, the foundations were laid for significant firms to emerge from this base. San Diego has since grown to be one of the three major centres of industrial biotechnology in the US, along with Boston, and Northern California. Indeed, the regional biotechnology industry is larger than the entire UK industry in this field (Caspar, 2007).

- *Building an integrated environment for university technology transfer and entrepreneurship activities.* When a university establishes 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 regional-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. A good example of this approach to building an innovation Space is the Flemish Catholic University of Leuven (KUL) and its technology transfer office Leuven R&D, which have become the core of a thriving regional innovation network including incubators, science parks, business centres, venture capitalists, spin-off companies and international R&D intensive

companies, several networking initiatives and technology clusters[12] (Debackere, 2000; Debackere and Veugelers, 2005).

- *Relocation of artists to declining urban districts to stimulate arts/technology-based economic renewal.* For example, the creative use of New York City zoning authority, allowing professional artists to move into abandoned industrial buildings and organize themselves as a Foundation for the Community of Artists, preserved Soho for a time as a low-cost space for qualified artists and regulated the transition of a declining manufacturing district into Soho as the arts equivalent of a Science City based on advanced academic research (Etzkowitz and Raiken, 1980). 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. For example, Barcelona's *@22* urban science park project aims to recycle an old industrial district into a platform for knowledge-based enterprises. *@22* has been very successful in attracting national and multi-national firms to locate in Barcelona, but its top-down design failed to take account of and incorporate spontaneous bottom-up developments, like the artists influx, that could have made it an even greater success as a hybrid technology/arts district, with a greater potential to spawn creative industries at the interface. Recently the *@22* leadership realised the earlier error of calling in the police to remove the artists and developed a scheme to attract them back.

c) The Consensus Space is the set of activities that bring together the Triple Helix system components to brainstorm, discuss and evaluate proposals for advancement towards a knowledge-based regime. Even when the initiative comes from a particular strand of the Triple Helix, it needs to draw actors from other spheres into a collaborative process. Through cross-fertilizing diverse perspectives, ideas may be generated and results may be achieved that actors are not likely to have accomplished individually. The Consensus Space has a broad coverage of the governance concept, including government and non-government actors who interact continuously to exchange resources and negotiate shared purposes. Although government does not occupy a privileged position, it can participate and take an initiating role, like others. That contributes to shifting the state boundaries towards more transparent

[12] See http://lrd.kuleuven.be/en/hitech

delineations between public, private and voluntary sectors: "*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" (*Kuhlmann, 2001, p. 957). This interaction is rooted in trust and is regulated by rules of the game negotiated and agreed by the participants. Organizations in the Consensus Space are interdependent: rather than seeing themselves as isolated entities, firms, universities and local government actors begin to see themselves as part of a larger whole, or in some cases of a newly-invented identities like Oresund (linking Copenhagen in Denmark and Skane in Southern Sweden) or the Leuven-Aachen-Eindhoven Triangle, which take hold at various levels of success, other times a reviving traditional locality like Norrköping, Sweden (Svensson, Klofsten and Etzkowitz, 2012). Achieving consensus may make the difference between an environment with untapped resources and one that has put them to use to achieve economic and social development. Several ways of creating a Consensus Space are possible, including:

- *Creation or transformation of an organization to provide a home for brainstorming, analysis of problems and formulation of plans*. Examples include the Pittsburgh High-Tech Council, the Petropolis Technopole in Rio de Janeiro State (Mello and Rocha, 2004), or the Board of the Recife Brazil Science Park, explicitly representing key local innovation actors playing a "quasi-political" role for enhancing the local innovation capacity. Similarly, the Knowledge Circle of Amsterdam meets regularly to brainstorm ideas for enhancing knowledge-based development. After-hours clubs in New York City can also be considered as a Consensus Space, providing venues for artists, fashion designers and other creative individuals to develop new projects across arts and fashion disciplines (Currid, 2007).
- *Provision of access to the resources required to implement a project.* This can be achieved through the very process of including actors from different backgrounds in the strategy review and formulation process. An example in this sense is the 1930's 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.

- *Providing solutions to conflict or crisis situations*, such as socio-economic crises caused by loss of manufacturing industries and failure to create alternative industries, financial and social crises, etc. (Etzkowitz et al. 2008). This was the case of the US facing the first wave of loss of manufacturing industries to foreign competitors in the 1970s, which triggered a compromise between opponents and proponents of direct government support for industry, a controversial concept in a national system where industry was expected to be the prime mover and source of innovation, while the firm, led by 'heroic entrepreneurs', was the protagonist. Japan faced economic and social stasis in the 1990s, when the production capacities of national manufacturing industries were increasingly outsourced abroad, leaving a gap that could not be filled by a real estate bubble that eventually burst, or by emerging companies that proved to be too weak to restart the economy. A shift to a knowledge-based economy was sought, in which universities would play a greater role, moving on from the position of R&D labs for industry they had played earlier. Sweden's movement of leading corporations and entrepreneurs abroad in the early 1990s or mergers with foreign firms that also outsourced economic activities abroad caused a financial crisis and a policy-making dilemma of whether to continue to support a relatively small group of older, large corporations, several of which, like Volvo and Saab, had become branches of multi-national corporations, or to shift focus to firm formation as a strategy for discontinuous innovation in emerging technologies. The dilemma was solved by adopting a start-up culture to revive the national industrial base with large national participation. Brazil's strategy to address persisting extremes of wealth and poverty included various government policy measures encouraging innovation as a renewal and growth strategy, made possible by the introduction of the Innovation Law in 2004 (*ibid*.)

5. FORMATION AND FUNCTIONING OF THE TRIPLE HELIX SPACES

The formation of the Knowledge, Consensus and Innovation Spaces is analytically conceptualized as a two-stage process:

(i) First stage - Formation of a "stem cell space" through interaction of the university, industry and government spheres

Triple Helix spheres get closer together in a gradual process and start to overlap, creating what we label a "stem cell space". This will be further differentiated in the next stage into a Knowledge, Innovation or Consensus space under the influence of specific triggers that are the functional equivalent of the biological triggers determining the formation and differentiation of living stem cells into various specialized cell types. Figure 2 presents the formation of a "stem cell space" in a 3D adaptation of the *Cassini ovals*[13], showing four configurations of the transition from independent to overlapping spheres that are equivalent to the transition from the *laissez-faire* to the *balanced model* represented previously in Fig.1. This is a simplified representation of the interaction among the university, industry and government institutional spheres, profiling relatively equal contributions of the spheres to the formation of a "stem cell space". In real life, the contributions of the three spheres may be more or less different from this simplified representation, i.e. there can be different degrees of involvement of the spheres. This is in fact the main factor that induces the substitution mechanisms discussed in Section 3, whereby the stronger sphere 'takes the role" of the weaker one or enhances its development.

Fig. 2 - Interaction between the Triple Helix institutional spheres in the formation of a Space

a. Institutional spheres apart: a *laissez-faire* regime.

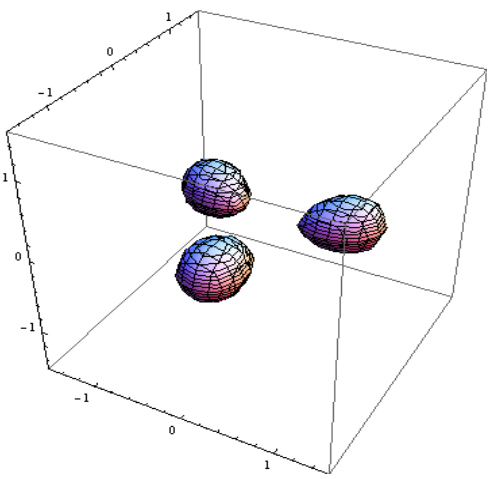
b. Institutional spheres getting closer together and starting to interact.

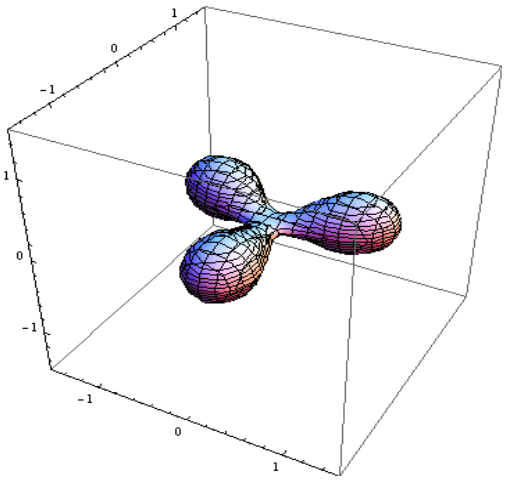
c. Institutional spheres increasingly overlapping

d. Institutional spheres overlapped in a balanced regime. Formation of a "stem cell space".

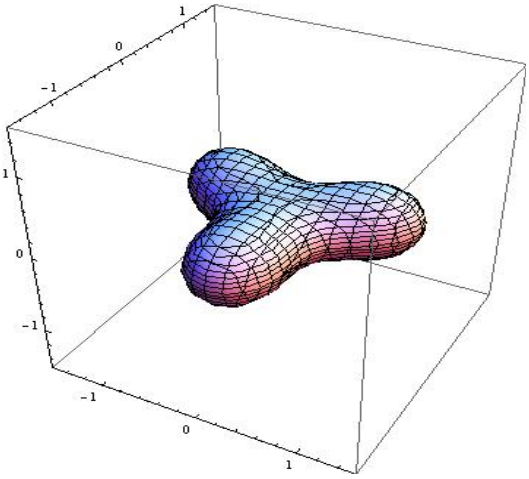
(a) (b)

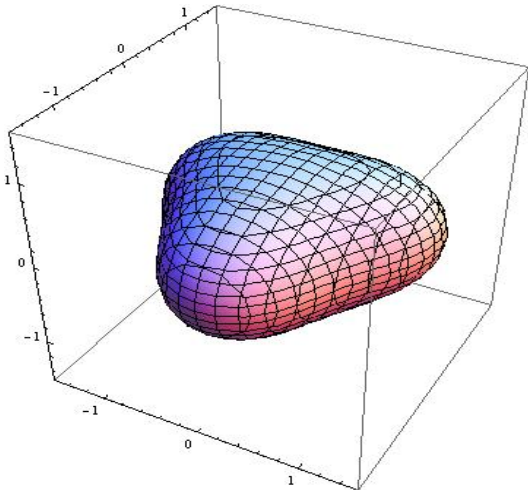
[13] The Cassini ovals (ellipses) are a family of curves identified by the astronomer Giovanni Cassini in 1860, which he believed defined the path the Earth takes around the Sun. A Cassini oval is a plane curve defined as the set (locus) of points in the plane where the product of the distances from the point to two fixed points situated at a distance 2a apart is a constant called b^2. The Cartesian equation of a Cassini oval is $((x-a)^2 +y^2)((x+a)^2 +y^2) = b^4$, where the x and y are two points in the plane. The general appearance of the oval 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, while at a = b it is the same as the "Bernoulli's lemniscate" that was documented about 14 years later. Here we present an adaptation of the Cassini ovals from two to three spheres, to accommodate our three institutional spheres, the principle remaining the same.





(c) (d)





(ii) Stage 2 - Differentiation of the "stem cell space"

The differentiation of a "stem cell space" into a Knowledge, Innovation or Consensus Space is achieved through mobilization of specific actors, relations and resources and the creation of new institutional formats, under the influence of specific local or regional needs, features of the interacting Triple Helix spheres and of their environment. We see this process similar to the stem cell differentiation determined by the interaction of a cell's genes with the physical and chemical conditions outside the cell, usually through signalling proteins embedded in the cell surface. The examples presented in Section 4 showing the formation of the Knowledge, Innovation and Consensus Spaces illustrate this differentiation.

Once the spaces are formed, they function in a continuous and diachronic transition from one space to another, occurring in different directions as a non-linear process. The Consensus Space is a key factor for catalysing the interaction between the Knowledge and Innovation Spaces when they are present, or for speeding up their development when they are weak or absent. When a Knowledge Space exists without a Consensus Space, full advantage is unlikely to be taken of its potential due to the lack of a convening and organising process to create the intermediary and transfer organisations and networks—the Innovation Space - that are the breeding ground of new knowledge-based clusters. The directions of transitions depend on different regional circumstances and also on different stages of regional development that we defined elsewhere in a four-stage model of regional growth and renewal (Etzkowitz and Klofsten, 2005), as follows:

(1) *Genesis*: creating the idea for a new regional development model;
(2) *Implementation*: starting new activities and developing infrastructure to realise the idea;
(3) *Consolidation and adjustment*: integration of activities to improve the efficiency of the new activities and infrastructure;
(4) *Self-sustaining growth and renewal of the system* by identifying new areas of growth.

At the Genesis stage, the Knowledge and Consensus Spaces are of key importance for initiating the Innovation Space. A transition from the Consensus Space to the Knowledge Space, and then to the Innovation Space, cutting across all the subsequent stages is identified in the case of the New England Council from the 1920s to 1950s. The creation of the Council by the Governors of the six New England states exemplifies the Consensus Space, which put together resources 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 raw materials and 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, including MIT, Harvard and a wide range of other academic institutions, which represented a strong Knowledge Space. They focused on enhancing 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 the creation of the Innovation Space.

A transition from the Knowledge Space to a Consensus Space is salient in 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).

Yet another situation is when one space becomes the basis for the enhancement of the others, spanning across all the four development stages described above. The development of Stockholm's Kista Science City exemplifies how a successful Consensus Space further enhanced a knowledge- and business-intensive platform created through the interplay between the Knowledge and the Innovation Space. In 2000 Stockholm's business community, academia and municipalities draw up a joint vision of the future to develop the Kista Science Park, which was already an established ICT centre of national and international prestige, also known as Sweden's Silicon Valley in the late 1980s, into a Science City. To implement this vision, Kista Science City AB is created and is soon ranked by Wired Magazine 2nd alongside similar developments in Boston and Israel. In 2002, the IT-university is opened as a joint venture between the Royal Institute of Technology KTH and the University of Stockholm, and new business networks are formed in Kista Science City's growth areas, especially ICT. In 2010, Kista Science City counted over 1,000 ICT companies and over 5,000 ICT students and scientists, a high concentration of expertise, innovation and business opportunities within ICT that is unique in Sweden[14].

[14] Selected from 'A History of Kista Science City' at: http://www.adimoserver.se/adimo4/(S(kokri4qeowj3nyvt0tkb1s45))/site/kista/web/default.aspx?p=1546&t=h401&l=en.

6. RELEVANCE OF TRIPLE HELIX SYSTEMS FOR KNOWLEDGE-BASED REGIONAL INNOVATION STRATEGIES

Regional innovation policies have traditionally focused on 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). Other priorities included 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). These efforts are generally subscribed to two main approaches to knowledge-based regional innovation and development: (i) an **exogenous** vision of attracting innovative high-tech firms to relocate in the region, as a modern twist of the traditional approach of attracting industrial branch plants, and (ii) an **endogenous** vision of creating an underlying science and arts base, as a mechanism to jumpstart the formation of knowledge-based firms and creative industries.

Exogenous knowledge-based regional development strategies based on relocation/attraction of firms from elsewhere, often subsidiaries or R&D centres of large multi-nationals, rely on marketing local assets, such as trained workforce, good infrastructure and living conditions. This approach originates in the neoclassical view that firms' decisions are responsive to small differences in input prices and will prefer locations with lower factor prices (Feldman and Francis, 2004). Exogenous strategies are usually promoted on a top-down basis, by active external factors such as central governments, private banks or transnational firms, who inject resources from outside the region to create jobs, wealth and a larger local tax base. External investments as key inputs for regional development come in response to improved infrastructure, fiscal incentives and programmes provided by federal or state 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). However, this top-down approach may have only limited effectiveness if the pool of firms that can be attracted, no matter how good the offer, is reduced by the decline of many manufacturing industries, and if the local knowledge assets are not strong enough to sustain the activities of the relocated units. This attraction strategy is most likely to fail and turn into a "cargo cult"

fantasy (Massey et. al, 1992), if a region does not have a 'critical mass' of activity in a particular field, so that the attracted units join a thriving cluster and relevant peers, like pharmaceutical firms moving to northern New Jersey or Boston, and if a human resources attraction strategy is lacking[15].

Endogenous knowledge-based regional development strategies recognise that local factors, such as strong knowledge base, 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, having fewer resources than larger firms, are more dependent on the resources of their local environments. Therefore, creating the infrastructure for local knowledge creation and knowledge-based firm formation and growth is the essence of an endogenous high-tech regional development strategy (Feldman and Francis, 2004). Endogenous strategies are usually promoted bottom-up, emphasising 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 (Parker, 2001).

Practice has shown that exogenous and endogenous knowledge-based regional development strategies are not mutually exclusive and in fact can support each other[16]. Both strategies comprise various combinations of the Knowledge, Innovation and Consensus Spaces, in a continuous transition from one space to another or triggering the formation of a space that hasn't been crystallised yet. The transition speed and the degree of combining exogenous and endogenous strategies depend on the reaction time and development of each individual space: the spaces remain structurally coupled to various extents as they rely on the underlying communication between the Triple Helix actors involved. **The spaces are thus a central**

[15] For example, integrating research groups and centres into local networks, or offering research resources and better work conditions to attract distinguished researchers rather than develop young researchers.

[16] The Brazilian popular cooperative incubator model was invented bottom-up by a university incubator and a NGO campaign against hunger to teach poor people from the *favelas* how to organise a cooperative and create their own jobs. The popular cooperative was subsequently spread across Brazil by a federal government programme (Almeida, Mello and Etzkowitz, 2012). U.S. federal research funding during WWII and in the post-war stimulated the development of both Boston and Silicon Valley and acted 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. The large-scale research programmes in data mining funded by the Defence Advanced Research Projects Agency (DARPA) at Stanford and a few other universities 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.

element for the capacity of Triple Helix systems to integrate exogenous and endogenous strategies for knowledge-based regional development strategies and amplify synergies between them. Therefore, the promotion of measures that support the formation and consolidation of the spaces is essential in designing Triple Helix-based regional innovation strategies (see Section 8 for a discussion of such measures).

7. TRIPLE HELIX SYSTEMS AND OTHER INNOVATION SYSTEMS APPROACHES

The Triple Helix model has often been used in the innovation theory and practice as an alternative approach to the 'innovation systems' concept, which was introduced in the mid-1980s to understand innovation and economic growth in evolutionary systems where institutions and learning processes are of central importance (Freeman, 1987, 1988; Freeman and Lundvall 1988). The concept was refined as 'national innovation systems' (NIS) delineated by a set of innovation actors (firms, universities, research institutes, financial institutions, government regulatory bodies, etc.), their activities and inter-linkages at the aggregate level (Freeman, 1988; Dosi et al 1988; Lundvall, 1988; 1992; Nelson, 1993; Nelson and Rosenberg, 1993; Edquist, 1997, 2005). The 'national' dimension of innovation systems[17] favoured user-producer interactions through cultural and institutional proximity and localised learning (Lundvall, 1992), but became increasingly blurred due to business and technology internationalisation extending technological capabilities beyond national borders, and the growing integration of innovation systems, driven by the economic and political processes, e.g. the European Union consolidation. As the NIS approach did not fully capture the interactions between innovation actors at more aggregated levels of analysis, an examination of more disaggregated levels of the innovation system was necessary for a dynamic view of the innovation processes (Carlsson *et al.*, 2002):

- **Regional Innovation Systems** (e.g. Storper, 1995; Cooke, 1996; Maskell and Malmberg, 1997) emerged in the context of the increasing regionalisation of the early 1990s at technological, economic, political or cultural levels in many countries. The concept comprised for example, a set of regional actors aiming to reinforce regional innovation capability and competitiveness through technological learning (Doloreux and Parto, 2005), regional 'technology coalitions' arising from geographical

[17] In the sense of specific national factors, like history and culture, institutions, laws and policies that shaped technological capabilities of a country.

distribution of economic and technological effects over time (Storper, 1995), or dynamic, self-organizing business environments (Johannson et al. 2005), etc.

- **Sectoral Innovation Systems** (Breschi and Malerba, 1997; Malerba, 2002) examine industry structure as a determinant of firm's performance heterogeneity and explore coordination forms in supply chains (hierarchy, market and hybrid forms);
- **Technological Systems** (Carlsson & Stankiewicz, 1991; Carlsson, 1997; Bergek et al., 2007) focus on the network of agents that interact in function of a specific technology.

Here, we compare and contrast these innovation systems approaches with Triple Helix systems in terms of some aspects identified as key flaws in the former:

a) Diffuseness and conceptual heterogeneity: the innovation systems described above (national, regional, sectoral, technological) are seen as a set of organizations and institutions interlinked by complex relationships (Edquist, 2005), but these linkages are relatively little described (Godin, 2007; Bergek, 2008), with the notable exception of some studies of inter-industry technology flows that asses the degree of sectoral integration amongst industries, but do not capture other important elements, such as intra-sectoral flows, tacit and codified knowledge flows (Scherer 1982; Pavitt 1984; Archibugi 1988; Howells, 1996). In contrast, the components, relationships and functions of Triple Helix systems provide a fine-grained description of the actors and relationships between them, including a vision of the functioning of the system through a boundary-spanning diachronic transition between the Knowledge, Innovation and Consensus Spaces.

b) Strong focus on institutions and low visibility of the role of individuals in the innovation process: institutions (especially firms[18]) are seen as key explanatory factors for understanding why some innovation processes in certain regions, countries or sectors fare better than others (Edquist, 1997; Edquist, 2004; Lundvall, 2003). However, various definitions of 'institutions' among studies leads to considerable confusion about what institutions are, what role they play and what are the mechanisms through which they work (Carlsson, 2003)[19]. Moreover, this strong reliance on institutions neglects the individual

[18] As Lundvall (2003, p. 14) points out: "We know that firms are the units that play the most important role in the innovation system and that it matters for innovation and for how innovation affects performance how firms organise themselves".

[19] Carlsson (2003) refers to Freeman (1987) and Nelson & Rosenberg's (1993) focus on institutions as networks or organizations supporting technical innovation, Lundvall's (1992) look at the "institutional set-up" as the rules

innovator. Triple Helix systems accommodate both the institutional and the individual roles in innovation, the former through the 'single-sphere' and 'multi-sphere' (hybrid) organizational formats associated with the university, industry, government institutional spheres, and the latter, with concepts like the 'innovation organizer' and 'entrepreneurial scientist' that provide a phenomenology of behavioural types (Schutz, 1959) and can span one or more institutional spheres.

c) System boundaries: in the 'traditional' approach to innovation systems, boundaries are spatially defined by national or regional borders, or by industry structures that usually cross geographic boundaries (Carlsson et al., 2002; Edquist, 2005), or by technologies that typically cross both geographic and sectoral boundaries (Hekkert et al., 2008). In the Triple Helix systems, sectoral and technology boundaries are superseded by the boundary permeability among the institutional spheres that allows regional and local resources to be combined for realising joint objectives and new institutional formats in any of the Knowledge, Innovation and Consensus spaces. Boundary permeability is also an important source of organisational creativity, as individuals move among the spheres and engage in recombination of elements to create new types of organizations. Spatial aggregation in Triple Helix systems is particularly important at the regional level, for stimulating the creation and consolidation of the Knowledge, Innovation and Consensus Spaces and their capacity to integrate various regional development strategies (endogenous and exogenous).

8. CONCLUSIONS AND POLICY IMPLICATIONS

This paper introduced the concept of Triple Helix systems as an analytical construct that systematizes the key features of university-industry-government (Triple Helix) interactions into an 'innovation system' format defined according to systems theory as a set of components, relationships and functions. This perspective provides an explicit framework for the systemic interaction between Triple Helix institutional actors. It also builds upon the structure/process view of innovation systems (Bergek et al. 2008) that sees the processes within an innovation system as a necessary complement to the structural elements of the system. We define the components of Triple Helix systems, acknowledging three important distinctions: between R&D and non-R&D innovators; between "single-sphere" and "multi-

or regimes that determine behaviour, and Carlsson and Stankiewicz's (1991) view of institutional arrangements defining both regimes and organizations.

sphere" (hybrid) institutions; and between individuals and institutions. The relationships between components are synthesised into four main types: collaboration and conflict moderation, collaborative leadership, substitution, and networking. The functions of the Triple Helix systems are defined as a set of activities in what we call the "Knowledge, Innovation and Consensus Spaces". We envision the formation of the spaces as a two-step process of: (i) interaction of the Triple Helix institutional spheres and formation of a "stem cell space", followed by (ii) the differentiation of the "stem cell space" into a Knowledge, Innovation or Consensus Space through mobilization of actors, relations and resources, and creation of new institutional formats. The differentiation is triggered by specific local or regional needs and features of the interacting Triple Helix spheres, similar to the stem cell differentiation induced by signalling proteins embedded in the cell surface.

We also discuss the functioning of the spaces as a non-linear, diachronic transition from one space to another, in different directions among them, with one space catalysing the interaction between the others when they are present, or speeding up their development when they are weak or absent. We relate the direction of transitions to different regional circumstances and development stages, and highlight the relevance of the Triple Helix systems to regional innovation strategies, due to the capacity of the Knowledge, Innovation and Consensus Spaces to combine endogenous and exogenous strategies and amplify the synergies between them. We conclude with a comparison of Triple Helix systems with other innovation systems, highlighting specific features of the former that can resolve some of the flaws identified in the latter, e.g. diffuseness and conceptual heterogeneity, strong focus on institutions and low visibility of individuals in the innovation process, and the way system boundaries are addressed in both approaches.

The analytical construct of Triple Helix systems we propose here still needs a much better understanding of several issues and their policy implications:

1. **The development of the Knowledge, Innovation and Consensus Spaces**

First, the formation and differentiation of the spaces depend essentially on the motivation of the Triple Helix actors to engage in joint projects and set common goals. This is not an easy process, as setting joint agendas often involves a major change of vision, crossing organizational silos, thinking beyond the boundaries of a single institutional sphere, harmonizing institutional and individual objectives, resources, cultures, etc. Such outcome can be accelerated by top-down or bottom-up initiatives that need a favourable environment

to reach fruition, but also require policy measures that better integrate innovation and entrepreneurship within the larger socio-economic context, especially research, education, labour market and development policies.

Secondly, we also need to understand more about the growth of the spaces over time, especially in relation to the four regional development stages outlined in Section 6 above, and about the functional requirements that would need to be in place for supporting each development stage. For example, we know that economic downturn and political crises are a major catalyst for the creation of the Consensus space, but how do Consensus spaces get created in times of economic upturn? Or how can cross-institutional leadership be inspired to arise there where it has been conspicuously absent? A comparative analysis of the creation of Consensus spaces over a variety of regional conditions in different historical periods and stages of regional development will be most useful in order to clarify what impetuses lead Triple Helix actors to come together to create a Consensus space. We also need to refine our analysis of good practice in creating Innovation spaces: what are the conditions under which importation of organisational innovations work and when do they impede development? What methodology should be developed for such an analysis, what gaps need to be filled with what type of organisational innovation, what elements need to be brought together to create organisational innovation? In the past, the venture capital model was created from such an analysis (Etzkowitz, 2002); what form would such analysis take in our days?

2. Assessing the performance of Triple Helix systems by means of hybrid indicators that capture dynamic processes at the intersection of the university, industry and government institutional spheres rather than within single spheres. Such indicators are currently very rare. For example, among the 25 indicators of the 2011 Innovation Union Scoreboard[20], only one - public-private publications[21] - captures the effect of collaboration between the university and industry spheres, while most of the others describe single-sphere effects (e.g. the indicators under the 'Firm activities' and 'Output' categories reflect firm-specific processes, and some of the indicators under 'Enablers' reflect some academic processes). The OECD Science,

[20] See details at http://ec.europa.eu/enterprise/policies/innovation/files/ius-2011_en.pdf.

[21] This indicator is part of the University-Industry Research Collaboration Scoreboard produced by Leiden University, which provides an internationally comparative framework based on co-publications of at least one university and one private sector organization that are usually business firms in manufacturing and services or for-profit contract research organizations. See http://www.socialsciences.leiden.edu/cwts/research/uirc-scoreboard-2011.html

Technology and Industry Scoreboard 2011 has two such indicators: Government-financed R&D in business (government-industry interface), and Patents citing non-patent literature and average citations received per patent cited (industry-university interface). Also, the design of indicators that characterize the specific dynamics of each space may be a challenging process, especially for the Innovation and Consensus spaces. For example, the number of spin-offs graduated from university incubators could be a relevant indicator for the Innovation space, while the number of projects achieved with the involvement of Triple Helix actors could become a good proxy for the Consensus space.

The policy implications arising from the adoption of a Triple Helix systems approach to innovation focus particularly on the promotion of measures that support the formation and consolidation of the Knowledge, Innovation and Consensus spaces. For example, an important condition for strengthening the Knowledge Space is the achievement of a 'critical mass' of R&D and non-R&D actors, academic research and education resources in a local area. Strategies to develop this 'critical mass' could focus on: mapping regional/national actors (public and private research labs, firms, universities, arts and cultural organizations, etc.) and analyzing their evolution and future trends, understanding their priority-setting and the design of their agendas, scope of operations (regional, national, international) and regional impact. Policy initiatives may also be directed at developing human resources for R&D in sciences and arts at national/regional level, improving the labour market for researchers, promoting better policies for employment, education and training, immigration to attract world-class researchers, making research careers more available for various categories of the local population, especially women and minorities, reducing brain drain and improving brain gain.

Similar directions of action are important in developing the Innovation Space: (i) mapping of 'single' - and 'multi-sphere' (hybrid) institutions, in particular science parks, incubators, business/technology incubators; and (ii) promoting policies that support their formation and activity, creation of seed funds, increased participation of industry and other private stakeholders in public research priority-setting, licensing and exploitation of intellectual property rights (IPR) resulting from publicly-funded research, IPR awareness and training activities, fiscal measures to encourage the creation and growth of R&D-intensive firms and raise attractiveness of research careers, national and regional programmes to promote venture

capital funds and loans, improve access to debt and equity financing for research and innovation activities, risk capital, etc.

The formation and development of the Consensus Space can be accelerated by strengthening the dialogue and collaboration between national and regional innovation stakeholders and creating new platforms for communication, promoting collaborative governance measures, such as public consultation and feedback, collaborative leadership models and practices (e.g. Chrislip, 2002; Archer and Cameron, 2008).

The Triple Helix systems approach offers a broad perspective for understanding the sources and development paths of innovation. On the one hand, by introducing the Triple Helix model into a systems framework, key contributors to innovation and their interactions are specified; on the other, by introducing a systems perspective, the Triple Helix model is developed into a conceptual machinery for the advancement of innovation theory and practice. An innovation strategy centred on the Triple Helix systems can be an attractive perspective, especially for regions that aim to enhance their knowledge base and create "steeples of excellence" around research themes with commercial potential and innovative firms that could realize that potential. Schumpeter's theory of creative destruction shows how outmoded economic regimes disappeared; the Triple Helix systems delineate how new regimes appear through creative reconstruction. By revealing "the workings of the engine", they provide new insights into the process of knowledge-based regional development that is often considered to be opaque and hidden, encouraging initiatives and practices that carry the seeds of innovative developments.

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