Triple Helix systems: an analytical framework for innovation policy and practice in the Knowledge Society

Marina Ranga and Henry Etzkowitz

Abstract: *This paper introduces the concept of Triple Helix systems as an analytical construct that synthesizes 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. Among the components of Triple Helix systems, a distinction is made between (a) R&D and non-R&D innovators; (b) 'single-sphere' and 'multi-sphere' (hybrid) institutions; and (c) individual and institutional innovators. The relationships between components are synthesized into five main types: technology transfer; collaboration and conflict moderation; collaborative leadership; substitution; and networking. The overall function of Triple Helix systems – knowledge and innovation generation, diffusion and use – is realized through a set of activities in the knowledge, innovation and consensus spaces. This perspective provides an explicit framework for the systemic interaction between Triple Helix actors that was previously lacking, and a more fine-grained view of the circulation of knowledge flows and resources within and among the spaces, helping to identify existing blockages or gaps. From a Triple Helix systems perspective, the articulation and the non-linear interactions between the spaces can generate new combinations of knowledge and resources that can advance innovation theory and practice, especially at the regional level.*

Keywords: *Triple Helix systems; knowledge space; innovation space; consensus space; university–industry–government interaction; innovation systems; regional innovation policy*

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Recent decades have seen a shift from innovation sources confined to a single institutional sphere, whether new product development in industry, policy making in government or the creation and dissemination of knowledge in academia, to the interaction among these three institutional spheres as the source of new and innovative organizational designs and social interactions. This shift entails not only various mechanisms of restructuring of the sources and development path of innovation, but also a rethinking of our main models for conceptualizing innovation (for example, national, regional, sectoral, technological innovation systems, the Triple Helix, and so on) that may often fail to capture important innovation dynamics because of issues such as diffuseness and loose definition, methodological or performance measurement gaps.

The concept of the Triple Helix of university–industry–government relationships initiated 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 and government in the Knowledge Society. 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 hybridization 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 – university, industry and government – as well as at their intersections.

Through subsequent development, a significant body of Triple Helix theoretical and empirical research has grown over the last two decades that provides a general framework for exploring complex innovation dynamics and for informing national, regional and international innovation and development policy-making.[1,2] This body of research has an implicit systemic dimension that arises primarily from the vision of Triple Helix interactions as manifestations of social systems, but does not provide an explicit analytical framework for conceptualizing Triple Helix interactions into an innovation system.

The novel analytical concept of Triple Helix systems introduced in this paper aims to fill this gap. Triple Helix interactions (heretofore loosely referred to as a 'metaphor' or a 'framework') are synthesized into an 'innovation system' format that encompasses structural and functional concepts of innovation systems theory (Carlsson and Stankiewicz, 1991; Carlsson *et al*, 2002; Carlsson, 2003; Edquist 2005; Bergek *et al*, 2008). Thus, Triple Helix systems are defined as a set of the following.

(1) *Components*, consisting of the institutional spheres of university, industry and government, each with a wide array of actors, among whom a distinction is made between: (a) individual and institutional innovators; (b) R&D and non-R&D innovators; and (c) 'single-sphere' and 'multi-sphere' (hybrid) institutions.
(2) *Relationships between components* (technology transfer, collaboration and conflict moderation, collaborative leadership, substitution, and networking).
(3) *Functions*, in the sense of competencies of the system components that determine the system's performance. The main function of a Triple Helix system is seen in a broader sense, that of generation, diffusion and utilization of knowledge and innovation. This function is realized not only with the techno-economic competencies described in innovation system theory, but also with entrepreneurial, societal, cultural and policy competencies that are embedded in what we call the 'Triple Helix spaces': the knowledge, innovation and consensus spaces.

Triple Helix systems provide a fine-grained view of innovation actors and the relationships between them, in a vision of a dynamic, boundary-spanning and diachronic transition of knowledge flows within the system. Triple Helix systems accommodate both institutional and individual roles in innovation and explain variations in innovative performance in relation to the development of and articulation between the knowledge, innovation and consensus spaces. Transcending sectoral or technology boundaries, Triple Helix systems emphasize boundary permeability among the institutional spheres as an important source of organizational creativity, allowing individuals to move within and between the spheres and engage in recombination of elements to create new types of organizations. Empirical guidelines for policy makers, university and business managers can be derived from this analytical framework, in order to strengthen collaboration among Triple Helix actors and enhance regional development.

The paper is organized as follows. The next section introduces the conceptual framework of Triple Helix systems and summarizes the literature upon which it relies. The subsequent three sections provide a detailed

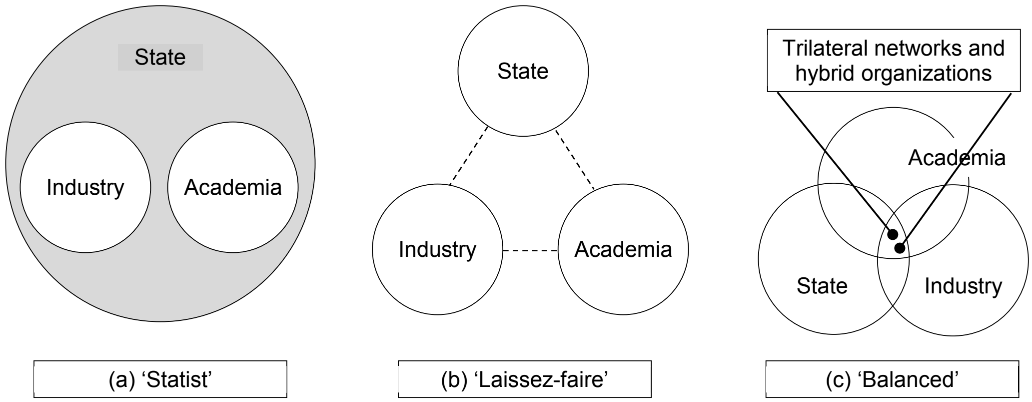

Figure 1. Triple Helix configurations.
Source: Etzkowitz and Leydesdorff (2000).

account of the structural elements of Triple Helix systems: components, relationships between components, and functions. The penultimate section describes the formation and functioning of Triple Helix spaces; and the final section provides a summary of the findings, a discussion of the policy relevance of Triple Helix systems for regional innovation policy, especially in developing countries, a set of policy recommendations and directions for further research.

Triple Helix systems: conceptual framework

A substantial body of the Triple Helix literature has been developed over the last two decades that can be broadly viewed from two complementary perspectives.

First, there is the *(neo-) institutional perspective*, which examines the growing prominence of the university among innovation actors through national and regional case studies (for example, in Latin America: Mello and Rocha, 2004; Etzkowitz, Mello and Almeida, 2005; Saenz, 2008; Bianco and Viscardi, 2008; Luna and Tirtido, 2008; in Africa: Konde, 2004; Kruss, 2008; Booyens, 2011; in the USA: Campbell *et al,* 2004; Feldman and Desrochers, 2004; Boardman 2009; Wang and Shapira, 2012; in Europe: Klofsten *et al,* 1999; 2010; Inzelt, 2004; Geuna and Nesta, 2006; Lawton Smith and Bagchi-Sen, 2010; Geuna and Rossi, 2011; Svensson *et al,* 2012) and through comparative historical analyses (for example, Etzkowitz, 2002; Furman and MacGarvie, 2009). These studies look at various aspects of the university's 'third mission' of research commercialization and involvement in socio-economic development, such as forms, stakeholders, drivers, barriers, benefits and impact, university technology transfer and entrepreneurship, contribution to regional development, government policies aimed to strengthen university–industry links, and so on.

The (neo-) institutional perspective distinguishes between three main configurations in the positioning of the university, industry and government institutional spheres relative to each other (see Figure 1):

(1) A *statist* configuration, in which government plays the lead role, driving academia and industry, but also limiting their capacity to initiate and develop innovative transformations (as, for example, in Russia, China, and some Latin American and Eastern European countries);
(2) A *laissez-faire* configuration*,* characterized by limited state intervention in the economy (such as in the USA and some Western European countries), with industry as the driving force and the other two spheres acting as ancillary support structures with limited roles in innovation – universities acting mainly as providers of skilled human capital and government mainly as a regulator of social and economic mechanisms; and
(3) A *balanced* configuration, specific to the transition to a Knowledge Society, in which university and other knowledge institutions act in partnership with industry and government and even take the lead in joint initiatives (Etzkowitz and Leydesdorff, 2000).

The balanced configuration offers the most important insights for innovation, because the most favourable 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 new venues for interaction and new organizational 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, 2003, 2008). Through this creative process, the relationships among the institutional spheres of university, industry and government are continuously reshaped in 'an endless transition' (Etzkowitz and Leydesdorff, 1998), in order to enhance innovation by bringing forth new technologies, new firms and new types of relationships.

The second of the two perspectives is the *(neo-) evolutionary perspective,* inspired by the theory of social systems of communication (Luhmann, 1975, 1984) and the mathematical theory of communication (Shannon, 1948). From this perspective, university, industry and government are co-evolving sub-sets of social systems that interact through an overlay of recursive networks and organizations that reshape their institutional arrangements through reflexive sub-dynamics, such as markets and technological innovations (see, for example, Leydesdorff, 1996, 1997, 2000, 2006, 2008; Leydesdorff and Meyer, 2006; Dolfsma and Leydesdorff, 2009). These interactions 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 thus ensure the 'regeneration' of the system (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000). The interactions between the Triple Helix actors can be measured in terms of probabilistic entropy, which, when negative, suggests a self-organizing dynamic that may be temporarily stabilized in the overlay of communications among the carrying agencies (see, for example, Leydesdorff, 2003; Leydesdorff *et al*, 2006). The interaction is also captured by specific indicators (such as bibliometrics, patent indicators) that can provide insights into trends and patterns of public–private cooperation, its geographical concentrations and implications (for example, Kwon *et al,* 2012; Tijssen 2006, 2012; Azagra-Caro *et al*, 2010; Leydesdorff and Meyer, 2010).

Both these perspectives have an implicit, underlying systemic dimension of Triple Helix interactions originating from their vision of such interactions as manifestations of social systems characterized by action (Parsons, 1951; Parsons and Shils, 1951; Parsons and Smelser, 1956) and communication (Luhmann, 1975, 1984; Shannon, 1948). However, neither provides an explicit analytical framework for conceptualizing Triple Helix interactions as innovation systems. To fill this gap, we introduce the concept of Triple Helix systems as an analytical construct defined from the perspective of innovation systems theory, discussed briefly below and highlighting some relevant elements for our study.

The 'innovation systems' concept was introduced in the late 1980s to examine the influence of knowledge and innovation on economic growth in evolutionary systems, in which institutions and learning processes are of central importance (Freeman, 1987; Freeman and Lundvall, 1988). The systems perspective was used to understand better how institutional arrangements could facilitate interactions among economic actors in market as well as non-market transfer of knowledge (Carlsson, 2003). The concept was refined as 'national innovation systems' (NIS), which includes a set of innovation actors (firms, universities, research institutes, financial institutions, government regulatory bodies, and so on), their activities and their inter-linkages at the aggregate level (Freeman, 1988; Dosi *et al*, 1988; Lundvall, 1988, 1992; Nelson, 1993; Edquist, 1997, 2005). The 'national' dimension of innovation systems favoured user–producer interactions through cultural and institutional proximity and localized learning (Lundvall, 1992).[3] Nevertheless, it became increasingly blurred as a result of business and technology internationalization extending technological capabilities beyond national borders, and the growing integration of innovation systems, driven by economic and political processes, such as European Union consolidation.

Because the NIS approach did not fully capture the interactions between innovation actors, more disaggregated levels of the innovation system were introduced, such as the following.

- *Regional Innovation Systems* (for example, 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 has a broad definition: it encompasses, for instance, 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 distribution of economic and technological effects over time (Storper, 1995), or dynamic, self-organizing business environments (Johannson *et al,* 2005), and so on.

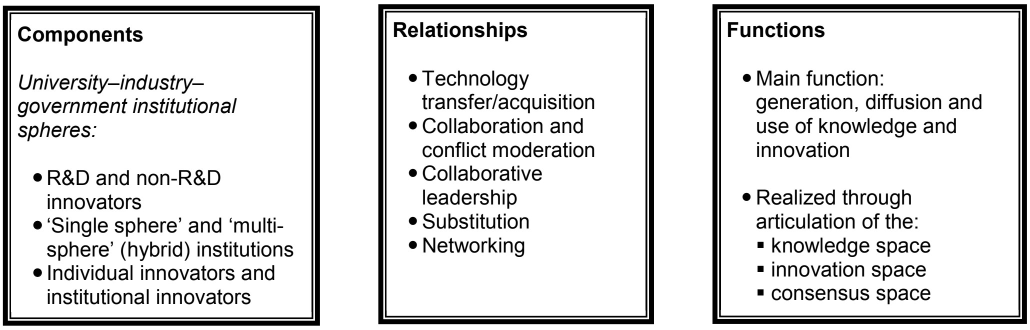

Figure 2. A synthetic representation of Triple Helix systems.

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

All these system frameworks are characterized by three elements (Carlsson and Stankiewicz, 1991; Carlsson, 1998, 2003; Carlsson *et al*, 2002; Hekkert *et al*, 2008), as follows.

(1) *Components (and boundaries) of the system*. The components include various actors that normally interact in the process of innovation (individuals and firms, higher education and research institutions, government agencies, financial and trade associations and other units making up the institutional infrastructure). The boundaries between components can be defined by geography or administrative units, as in the case of spatially-bounded systems (regional, national innovation systems), or by economic sectors or technologies, as is the case with spatially open systems (such as technology innovation systems or sectoral innovation systems).
(2) *Relationships among system components*, which include new knowledge combinations generated by the innovation actors, either through own efforts or by using technology transfer from other actors, provided they have sufficient absorptive capacity. Internal R&D capacity of the actors is essential in this process, but non-R&D (non-market) interactions are also important.
(3) *Functions of the system*, in the sense of competencies of the components that determine the system's performance. The main function of an innovation system is defined as the generation, diffusion and utilization of technology, while the competencies necessary to achieve this function are described in terms of four types of capabilities: (a) selective (strategic) capability; (b) organizational (integrative or coordinating) ability; (c) technical or functional ability; and (d) learning (adaptive) ability.[4]

Building on this structural characterization of innovation systems, combined with a structure/process approach of innovation systems (Bergek *et al,* 2008) that relates the structure of the system with the processes (dynamics and achievements) in which the system is involved, we define a Triple Helix system (Figure 2) as a set of the following.

(1) *Components (and boundaries):* the components are represented by the institutional spheres of university, industry and government, each with its own institutional and individual actors. Among these actors, a distinction is made between: (a) individual and institutional innovators; (b) R&D and non-R&D innovators; and (c) 'single-sphere' and 'multi-sphere' (hybrid) institutions. The boundaries identified in other innovation systems take on a new meaning in Triple Helix systems because they are no longer separating elements between the university, industry and government spheres, but unifying ones. Geographical, sectoral and technology boundaries are superseded in Triple Helix systems by the boundary permeability among the university, industry and government spheres. This allows a better circulation of people, ideas, knowledge and capital within and across the institutional spheres, stimulates organizational creativity as well as the combination of regional and local resources for realizing joint objectives and new institutional formats.
(2) *Relationships among system components:* the market- and non-market relationships between

system components, emphasized in the innovation systems theory and manifested primarily through technology transfer or acquisition, are also important in Triple Helix systems. In addition, we include here other relationships derived from the triadic nature of the interaction, such as: collaboration and conflict moderation, collaborative leadership and substitution. Networking, which is not a manifestation specific to triadic systems, but rather of the increasingly collective nature of science, technology and innovation, is also relevant here and is included among the relationships. These relationships are important because they reflect change-inducing, evolutionary social and economic mechanisms at work in Triple Helix interactions.

(3) *Functions of the system:* if innovation systems theory defines the main function of an innovation system as the generation, diffusion and utilization of technology (for example, Carlsson *et al,* 2002, p 235), we see the main function of a Triple Helix system in a broader sense, as that of generating, diffusing and utilizing knowledge and innovation. This goes beyond technology and involves a broader set of competencies that extend beyond the four types of competencies described by the innovation systems theory (selective, organizational, technical and learning abilities), to incorporate in addition entrepreneurial, societal, cultural and policy aspects. These competencies are manifested in what we call the 'Triple Helix Spaces': the Knowledge, Innovation and Consensus Spaces, which encompass these cumulated competencies and bring them to a next level as a result of multiple combinations that allow new opportunities for innovation.

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 sphere-specific actors. This obscures some specific institutional identities, missions, objectives and needs, and the way they influence the interaction dynamics. On the one hand, this simplified perspective can sometimes be beneficial, especially in contexts where one or more of the spheres 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, that simplified perspective is no longer sufficient. A more differentiated approach to 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. To substantiate this differentiated approach, we make three important distinctions between:

- Individual and institutional innovators;
- R&D and non-R&D innovators; and
- 'Single-sphere' and 'multi-sphere' (hybrid) institutions.

Individual and institutional innovators

Innovation systems focus predominantly on institutions (especially firms), which are seen as key explanatory factors in understanding why some innovation processes in certain regions, countries or sectors fare better than others (Edquist, 1997, 2005).

However, various definitions of 'institutions' in studies may be confusing about what institutions are, what role they play and what the mechanisms are through which they work (Carlsson, 2003).[5] In addition, this strong reliance on institutions gives low visibility to the individual innovator.

Triple Helix systems acknowledge the importance of individual innovators (scientists, business people, policy makers, students, entrepreneurs, venture capitalists, business angels, and so on) and their role in initiating and consolidating institutional processes. Individual roles in innovation are accommodated through concepts such as the 'innovation organizer' and the 'entrepreneurial scientist' that provide a phenomenology of behavioural types (Schutz, 1964) and highlight ways in which individual and institutional innovation initiate and reinforce each other.

- The *innovation organizer* is defined as a person who typically occupies a key institutional position, enunciates a vision for knowledge-based development and has sufficient respect and authority to exercise convening power to bring the leadership of the institutional spheres together (see examples in Box 1). Innovation organizers can come from any institutional sphere. They coordinate a mix of top-down and bottom-up processes and innovation stakeholders from different organizational backgrounds and perspectives, who come together to build a platform for new ideas, promote economic and social development and ensure agreement and support for their realization. A process of 'cross-institutional entrepreneurship' spanning the

Box 1. Innovation organizers.

In 1930s 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 that relied heavily on university-originated technologies and that included the invention of the venture capital firm (Etzkowitz, 2002). In mid-1990s New York, the Head of the New York Federal Reserve Bank took the lead in calling for high-tech development to be seen as the engine of New York's economy, as an alternative to finance. Later, in 2011, New York's Mayor Bloomberg took on the innovation organizer role with an initiative to attract to the city leading technological universities, like Cornell, to fill the gap in the region's innovation environment (Saul *et al*, 2011).

A relevant example in Europe is the general manager of Belgium's Catholic University of Leuven (K.U. Leuven), Koenraad Debackere, who has had a central role in organizing and promoting technology transfer and entrepreneurship at the university and in the region. He brought together ideas, people and resources from all the Triple Helix strands – the university, local government and the business community – as a K.U. Leuven professor, Managing Director of the university's technology transfer office, Chairman of the university's venture fund, co-founder and Chairman of Leuven Inc, the innovation network of Leuven high-tech entrepreneurs, as well as a board member of IWT-Vlaanderen, the Flemish government agency that supports science and technology development in Flemish industry.

The innovation organizer role can also be extended from an individual to an institution, 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 UK's West Midlands region. The consortium envisaged 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).

Triple Helix spheres is thus initiated for improving the conditions for knowledge-based development.

- 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 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) a direct interest in the formation of a spin-off firm and in taking a leading role in this process; (b) handing over these results to a technology transfer office for disposition; (c) playing a supporting role, typically as member of a Scientific Advisory Board; and (d) having no interest in entrepreneurship, but rather in firm formation as a 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 nearly always a collective phenomenon. A new high-tech firm typically takes off with the support of individuals with technical and business expertise backed by an experienced entrepreneur, constituting together the 'collective entrepreneur', because only rarely does a single individual embody all of these required elements. However, national cultural differences are important in this respect. In the USA, there is a strong ideology of individual entrepreneurship that usually suppresses the contributions of collaborators and pushes a single individual to the forefront (Freiberger and Swaine, 2000).[6] In contrast, in the Nordic countries – for example Finland – work is extremely collectively focused and it is unusual for the role of an individual in a workplace to be over-emphasized. In Sweden, individuals are culturally inhibited from attempting an entrepreneurial act unless backed up by a group, so that collective entrepreneurship is rather the norm.

R&D and non-R&D innovators

This distinction is based on whether or not there is in-house (intramural) R&D. It emerges from the recognition that R&D is not the only driver of innovation. Other factors can also drive organizational innovative capacity, such as firm/business unit size and industry effects (Cohen *et al,* 1987), intangible resources (Galende and Suarez, 1999), internal factors (Galende and de la Fuente, 2003), informal processes of learning and experience-based know-how (Jensen *et al*, 2007), technology adoption, incremental changes, imitation, and new combinations of existing knowledge (Arundel *et al,* 2008). In low- and medium–high-technology industries which are characterized by weak internal innovation capabilities, there are strong dependencies on the external provision of machines, equipment, software and suppliers, as well as on process, organizational and marketing innovations (Heidenreich, 2009).

- *R&D innovators* can be found in each of the university, industry and government institutional spheres and, beyond that, in the non-profit sector (for example, charities, foundations, professional/trade associations, service organizations, non-profit corporations and trusts). In universities, key R&D performers are academic research groups and interdisciplinary research centres; in the business sector, company R&D divisions or departments; in the government sector, public research organizations, mission-oriented research laboratories, and so on. 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 in a similar fashion 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 company units involved in non-R&D activities, such as design, production, marketing, sales, acquisition of technology or machinery produced elsewhere, customization or modification of products and processes obtained from elsewhere, personnel training and competence-building, interaction with users, acquisition of patents and licences, consultancy services, and so on. On a broader scale, non-R&D innovation is also present in technology transfer, incubation activities, financing, negotiation, creation and change of organizations, and so on. These activities are not confined to industry borders and can also be found in various forms in government and academia as well as in the non-profit sector.

'Single-sphere' and 'multi-sphere' (hybrid) institutions

This distinction arises from the transition from the Industrial to the Knowledge Society which is characterized by increasing knowledge-intensive activities, communication and interconnectivity between people and institutions, mobility of people and financial capital, delocalization and globalization of production sites, labour and social relationships, and so on. Elements such as generation and internalization of new skills and abilities required for integration into dynamic work environments, uneven development of scientific and technological (including organizational) 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.

- *Single-sphere institutions*, delineated within the boundaries of a single institutional sphere, whether university or industry or government, are characterized by rigid institutional boundaries, low levels of interaction with another institutional sphere, a high degree of specialization and work centralization, limited mobility of workers, and so on. Their functioning is specific to the *laissez-faire* configuration described in Figure 1.
- *Multi-sphere (hybrid) institutions* operate at the intersection of the university, industry and government institutional spheres and synthesize elements of each sphere in their institutional design. They are representative of the *balanced* Triple Helix configuration described in Figure 1. Technology transfer offices in universities and government research laboratories, industrial liaison offices, business support institutions (science parks, business and technology incubators, start-up accelerators), financial support institutions (public and private venture capital firms, angel networks, seed capital funds, and so on) can be included in this category. They have smaller-scale hierarchies, with fewer layers and less centralized decision-making, in order to increase flexibility and responsiveness to changing market demands. In addition, institutional boundaries are more permeable (Etzkowitz, 2012) because the single institutional spheres of university, industry and government become more laterally diversified and increase collaboration in order to improve work effectiveness. Subsequently, boundaries between the job categories involved in these hybrid structures become looser and jobs require greater sharing of tasks and knowledge.

Relationships among components of Triple Helix systems

Technology transfer

Technology transfer via markets or non-market interactions is recognized as the core activity in an innovation system (Carlsson *et al*, 2002, p 234). It is also important in Triple Helix systems because universities increasingly generate and transfer technology, especially in areas such as biotechnology, nanotechnology, ICT or medical technologies (for example, Cooke, 2004; Meyer, 2006; Van Looy *et al*, 2007; Wong, 2007; Lawton Smith and Bagchi-Sen, 2010). Due to their greater capacity to generate and transfer technology, universities are no longer just a traditional source of human resources and knowledge, but are also key innovation stakeholders, with ever increasing internal organizational mechanisms and resources allocated to this purpose rather than placing reliance solely on informal ties. Technology transfer offices, science parks, business incubators, start-up accelerators and venture capital capacities have been created as intermediary elements within university administrative structures in order to facilitate the capitalization of knowledge and ensure the interface with the external world.

Greater university involvement in technology transfer has also brought about greater university involvement in the protection of intellectual property, in order to manage ethically the uses of university inventions in the public interest that also had significant implications for regional economic development and self-generation of resources for university development – see Baldini (2006) for a review of literature on university patenting and licensing. The harmonization of the individual inventor and the university's interests regarding the development of an invention and the allocation of financial rewards became a key issue that took different forms in different countries – for example, the professors' privilege in Scandinavian countries (see, for example, Iversen *et al*, 2007; Mets, 2010).

The involvement of universities in technology transfer has also increased their capacity to provide graduates with entrepreneurial education and talent, who can contribute to economic growth through firm formation and job creation. Various forms of entrepreneurship education are now being delivered in universities around the world in order to develop entrepreneurial skills, theoretical and practical experience in developing a business, to stimulate new ways of learning and to achieve an entrepreneurial mindset as an additional asset in approaching careers. Academic entrepreneurship also has benefits for faculty, who can secure more research funding for academic projects and ensure the stability of their research laboratories and continuous engagement of the students employed by the laboratory, develop a greater responsiveness to the needs of local business and entrepreneurs and have the possibility of testing their expertise outside the university boundaries, often making an impact on the regional and national economy. Important gains have also been noted at the community level, where economic benefits such as job creation and tax revenues from university start-ups are combined with social and cultural benefits such as positive social perception of entrepreneurs, stronger bonds between the university and the community and increased attractiveness of the university and the region to national and international talent and investors. Gaining the status of 'university city' is very important for many cities around the world and offers them the possibility of access to highly-skilled employees, high-growth entrepreneurs and venture capital investment, often leading to the transformation of the region into a world-class entrepreneurial ecosystem (Ranga *et al*, 2013). Universities are also extending their capabilities from educating individuals to educating organizations, through entrepreneurship and incubation programmes and new training modules (Almeida *et al*, 2012).

Collaboration and conflict moderation

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 relating to common objectives and 'win–win' situations is all the more important given that the very nature of conflicts and tensions is changing in the Knowledge Society, in line with the changing nature of work, the workplace and organizations (Heerwagen *et al*, 2010). Useful analytical tools for exploring conflict moderation in Triple Helix systems can be taken from the organizational innovation and cross-functional collaboration literature (see De Clercq *et al,* 2009, for a detailed review), which identifies two key conflict dimensions: (a) *task conflict (functional, cognitive or constructive conflict)*, which is content-driven and is generated by differences of opinions of an organization's functional departments about particular tasks (Amason and Sapienza, 1997); and (b) *relationship conflict (dysfunctional, affective or destructive conflict),* which is person-driven and is generated by incompatibilities or clashes between different personalities in different departments, leading to negative feelings such as tension and frustration (Jehn and Mannix, 2001; Finkelstein and Mooney, 2003). Task conflict has been shown to play a positive role in innovation by leading to a reconsideration of dominant perspectives and beliefs in an organization and stimulation of original and divergent viewpoints (Van Dyne and Saavedra, 1996), while relationship conflict has a negative effect on the high-quality knowledge exchanges and decision-making (Amason, 1996; Jehn, 1995; Jehn and Mannix, 2001; Pelled *et al,* 1999).

In Triple Helix systems, task conflicts can sometimes arise within the university sphere, where 'third mission' activities clash with long established academic norms, procedures and reward systems. Many academics fear a loss of their research freedom or a weaker academic performance caused by the entrepreneurial engagement. Relationship conflict is sometimes found at the university–business interface because of cultural differences and diverging interests between firms and universities that may impede knowledge exchange and bring challenges on collaborative projects if not properly addressed. Potential sources of conflict can also be found both at the micro-level of interacting individuals, and at the meso-level of institutional frameworks, rules and regulations (or lack thereof) that can create obstacles for the collaboration (for example, a weak culture of collaboration and organizational silos, a lack of incentives for the entrepreneurial behaviour of academics, the obligation in some universities for faculty to take a leave of absence to develop a spin-off, bias in the reporting of results, scarcity of data to evaluate technology transfer activities, and so on).

Conflict resolution implies not only addressing institutional gaps and diverging institutional logics, better monitoring of university–industry relationships and the dissemination of best entrepreneurial practices, but also using social skills and dialogue to manage expectations, addressing individual fears and creating shared cultural spaces for knowledge exchange (Campbell *et al*, 2004; Mets *et al*, 2008; Goldstein, 2010; Bjerregaard, 2010). These conflict-moderating measures can be initiated and developed from both the university and industry sides, while the government helix can exert an additional moderating effect by promoting supportive policies and programmes (see, for example, Brazil's 2004 Innovation Law, which establishes the legal framework for public–private partnerships and provides incentives for building and strengthening collaboration between universities, research institutes and private companies; incentives to encourage the participation of universities and research institutes in the innovation process; and incentives for promoting innovation within private companies).[8]

Collaborative leadership

Collaborative leadership is an integral part of the collaboration and conflict moderation capacity. 'Innovation organizers' as individual or institutional leaders play a key role in this type of relationship. They can connect people from different sectors to bridge gaps, bring together differing views, generate consensus and balance conflicts of interest. They can integrate skills and enable people to develop their own competence according to specific challenges, foster change in thinking and practical implementation through vision and reflection, and create new opportunities for knowledge exchange (for example, Chrislip, 2002; Archer and Cameron, 2009). They can develop clear project charters, conduct joint problem-solving tasks and ensure a high level of project satisfaction by the individual members of the partnership (Ruuska and Teigland, 2009).

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, that of investment and provision of public venture capital – a traditional task for the industry sphere (see, for example, Huggins, 2008; 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 proprietary education and training solutions, often at the same high level as universities (see, for example, Pixar University, Intel Educator Academy, Cisco Networking Academy, Apple University).[9,10,11,12] 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, firms or regional development agencies – may come forward to set a future achievable objective (playing an Innovation Organizer role, as described above). *Substitution within spheres* is also possible, especially in ecosystems with small, low-tech firms with little or no R&D potential that find collaboration with vocational training institutions more attractive and suited to their needs than collaboration with the university (Ranga *et al*, 2008).

Networking

Networking in formal and informal structures at national, regional and international level is not a phenomenon unique to Triple Helix interactions, but is widely found in this case too, as a manifestation of the collective nature of science, technology and innovation. The aggregation may be stronger or weaker, depending on the network's age, scope, membership, activities and visibility in the public domain (the Association of University Technology Managers (AUTM), the European Technology Platforms and the Joint

Technology Initiatives are just three examples).[13] Networks have been described over the last decades under diverse labels, such as ‘techno-economic networks’ (Callon, 1992) and ‘networks of innovators’ (Cusumano and Elenkov, 1994; DeBresson and Amesse, 1991; Freeman, 1991) and have emerged as an organizational form better suited to the limitations of hierarchies and markets – ‘neither market nor hierarchy’ (for example, 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 been compared 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 *et al*, 1999). Networking reflects the growing non-linearity and interactivity of innovation processes (Kaufmann and Tödtling, 2001) and provides several benefits (Steinmueller, 1994).[14]

Functions of Triple Helix systems

The main function of Triple Helix systems to generate, diffuse and utilize knowledge and innovation goes beyond the technology function and four types of competencies (selective, organizational, technical and learning) described in the innovation systems theory. It incorporates a broader set of knowledge, learning, entrepreneurial, societal, cultural and policy competencies that are achieved in what we label the ‘Triple Helix spaces’: the knowledge, innovation and consensus spaces.

The knowledge space

The knowledge space encompasses the competencies of knowledge generation, diffusion and use of the Triple Helix components. The construction of this space is an essential step in the transition to a Knowledge Society and has the purpose of creating and developing knowledge resources in order to strengthen the local, regional and national knowledge base, to avoid fragmentation and to reduce the duplication of research efforts. To this end, knowledge resources can be aggregated locally within a region, nationally or internationally across regions (for example, the European Commission’s initiatives to consolidate the European Research Area) through a wide range of mechanisms, from dispersal or relocation of existing resources, to creation of new ones through institution formation, to physical and virtual networking. All these mechanisms also have social, cultural and policy dimensions, as exemplified in Box 2.

The innovation space

The innovation space consists in particular of the competencies of the ‘multi-sphere’ (hybrid) organizations and entrepreneurial individuals and institutions discussed earlier. Its ultimate purpose is the development of local innovative firms, in parallel with the attraction of talent and innovative firms from elsewhere, the creation and development of intellectual and entrepreneurial potential, and 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 formation of firms and provide the energy and focus for a variety of institution-formation projects (Schumpeter, 1951; Etzkowitz and Schaflander, 1969). The new institutional formats that thus emerge depend on the strengths and weaknesses of the actors involved, their motivations, aptitudes, location, entrepreneurial capacities, institutional support for new firm formation and level of local economic and technological performance (Mason and Harrison, 1992; Thwaites and Wynarczyk, 1996; Lee and Peterson, 2000). The new institutional formats need to be integrated into a broader, national or region-wide innovative and entrepreneurial environment that provides a broader range of services and support structures (for example, to market intellectual property, create spin-off firms, identify market opportunities and partners), and partner with local city and regional governments to secure resources in order to achieve their objectives.

The creation of an innovation space can take place through various mechanisms, including, for example, the creation of a university in regions without higher education capacity, building an integrated environment for university technology transfer and entrepreneurship or relocation of artists to declining urban districts to stimulate arts/technology-based economic renewal. As in the case of the knowledge space, all these mechanisms go beyond the single function of technology generation, diffusion and use and encompass entrepreneurial, social, cultural and policy competences, as exemplified in Box 3.

The consensus space

The consensus space is the set of competences that bring together the Triple Helix system components to engage in ‘blue-sky’ thinking, discuss and evaluate proposals for advancement towards a knowledge-based regime. Even when the initiative comes from a

Box 2. Mechanisms for the creation of a knowledge space.

1. *Dispersal of some national public research resources from more research-intensive regions to less research-intensive ones.* Some government research labs were 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, and to provide research capacity to regions where it had hitherto been lacking and so address the problems of the locality. This policy was eventually broadened 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 (Casas *et al*, 2000).
2. *Relocation and aggregation of existing research resources*. The North Carolina state used its political clout to induce the relocation of federal government labs from outside the state to the North Carolina's 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).
3. *Attraction of leading researchers through the foundation of a science-based university.* The San Diego branch of the University of California, gestated in the 1950s, became the basis for a leading high-tech complex and contributed to the transformation of San Diego from a naval base and military retirement community to a knowledge-based conurbation. The coalition of academic, business and political leaders that called for the founding of this campus recognized the attraction of leading researchers in fields with commercial potential, like molecular biology, as an economic development strategy. The strategy of the San Diego campus was replicated by the Merced campus, recently established as an 'entrepreneurial university' to promote high-tech development in an agricultural region, and create location-specific knowledge assets to induce new investment and create new value.
4. *Creation of new university resources to support the development of new industries or raise existing ones to a higher level.* The State University of Rio de Janeiro in Friburgo created a new campus providing an IT-oriented PhD programme to supply knowledge inputs to a neighbouring declining industrial region, rather than simply training support personnel for existing firms as might have happened on an undergraduate campus. In Norkopping, Sweden, in the wake of deindustrialization, a Council representing the city region's business and political leadership was established. It decided to create a university campus with advanced academic research groups to revive the paper industry, one of the local traditional industries (Svensson *et al*, 2011). The New York Inter-University Seminar on Innovation, bringing together innovation scholars and practitioners across the metropolitan region in the mid-1990s, through Triple Helix leadership, hypothesized the lack of an MIT-like academic institution as the missing link to catalyse the city's strong academic research base for economic development. This analysis eventually percolated to the city's leadership. Mayor Bloomberg's recent competition to fill the gap resulted in the creation of the Cornell-Technion Technology Graduate School and the upgrading of NYU and Columbia innovation initiatives. Amsterdam's mayor, working with the Amsterdam Economic Board, is currently engaged in organizing a similar initiative (according to Rik Bleeker, Amsterdam Economic Board, interview with the 2nd author, 17 May 2013).
5. *Virtual congregation of geographically dispersed groups from university and industry around common research themes, with government support.* The Canadian Networks of Centres of Excellence (NCE) brought together widely dispersed academic and firm research units, motivated to work together by large government sponsorship, 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.
6. *Networking of existing knowledge-based organisations and creation of new ones through collaboration among existing players, in order to become internationally competitive.* The Stockholm School of Entrepreneurship was created as a joint initiative of Stockholm University, Royal Institute of Technology (KTH), and more recently included the Royal Art College. The Oresund project, linking southern Sweden (Skane) and Copenhagen, included the creation of Oresund University, which encourages collaboration between universities on both sides of the strait that previously divided this cross-border region. The Karolinska Institute initiated a university-building strategy of incorporating several small schools in the biological sciences, nursing and other loosely related fields scattered across Sweden and even across the Norwegian border, in order to create a greater 'critical mass' of research, training and commercialization activities.

Box 3. Mechanisms for the creation of an innovation space.

1. *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 had 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. In this context, MIT moved to the next stage of regional development, from supporting existing industries to contributing to 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 1950s, the regional leadership of San Diego deployed this explicit model of a science-based entrepreneurial university as a strategy for the creation of a new science-based industry in a region that was heretofore known as a naval base and retirement community. A new campus of the University of California was created as part of a long-term strategy to foster industrial development, and recruited leading scientists in areas with both theoretical and practical potential, such as biotechnology. A few decades later, by assiduously pursuing the strategy of developing a critical mass of research groups and institutes in biotechnology-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 USA, along with Boston and Northern California. Indeed, the regional biotechnology industry is larger than the entire UK industry in this field (Caspar, 2007).
2. *Building an integrated environment for university technology transfer and entrepreneurship.* Over the last two decades, the Flemish Catholic University of Leuven (K.U. Leuven) and its technology transfer office Leuven R&D 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 (Debackere, 2000; Debackere and Veugelers, 2005).
3. *Relocation of artists to declining urban districts to stimulate arts/technology-based economic renewal.* 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). Barcelona's @22 urban science park project, aimed to recycle an old industrial district into a platform for knowledge-based enterprises, has been very successful in attracting national and multinational firms to locate in Barcelona. However, its top-down design failed to take account of and incorporate spontaneous bottom-up developments, like the influx of artists that could have made it an even greater success as a hybrid technology/arts district, with greater potential to spawn creative industries at the interface. Recently the @22 leadership realized the earlier error to remove the artists and developed a scheme to attract them back.

particular strand of the Triple Helix, it needs to draw actors from other spheres into a collaborative process, where the collaborative leadership and conflict moderation relationships between system components are most prominent. 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 reflects various aspects of the governance concept, in a broader sense, 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 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 newly-created identities such as Oresund (linking Copenhagen in Denmark and Skane in Southern Sweden) or the Leuven–Aachen–Eindhoven Triangle; and, at other times, of a reviving traditional locality such as Norrköping, Sweden (Svensson *et al*, 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 mechanisms for creating a consensus space are possible, from the creation or transformation of an organization to analyse problems and formulate solutions, to the provision of access to the resources required to implement a project, or provision of solutions to conflict or crisis situations (see Box 4 for details).

Formation and functioning of the Triple Helix spaces

The formation of the knowledge, consensus and innovation spaces is conceptualized as the result of the interaction between the university, industry and government spheres, which gradually get closer together and start to overlap. Figure 3 presents the formation of a space in a 3D adaptation of the Cassini ovals.[15] It shows four configurations of the transition from independent to overlapping spheres that are equivalent to the transition from the *laissez-faire* to the *balanced* configuration represented in Figure 1. This is a simplified representation of the interaction among the university, industry and government institutional spheres, profiling relatively equal contributions to the formation of a 'space'. In real life, there are different degrees of involvement of the spheres (asymmetrical contributions) to the 'space'. In fact, this different degree of involvement of the spheres is the main factor that induces the substitution mechanisms discussed above, whereby the stronger sphere 'takes the role' of the weaker one or enhances its development.

The 'space' thus created is considered as the functional equivalent of a 'stem cell space', which will further differentiate to become a knowledge, an innovation or a consensus space through the mobilization of specific components, relationships and resources and creation of new institutional formats, under the influence of specific environment factors, like local or regional needs, geographical location, local and regional resources and assets, and so on. We see this process as 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 mechanisms for the formation of the knowledge, innovation and consensus spaces presented above illustrate this differentiation.

Once the spaces have been formed, they interact with each other in a continuous and diachronic transition that occurs in different directions as a non-linear process. For example, the consensus space is a key factor in catalysing the interaction between the knowledge and innovation spaces when these are present, or for speeding up their development when they are weak or absent. Also, when a knowledge space or an innovation space exists without a consensus space, full advantage is unlikely to be taken of their potential due to the lack of a convening and organizing process to create the intermediary and transfer organizations and networks – the innovation space – that are the breeding ground of new knowledge-based clusters.

The directions of transition depend on different regional circumstances and different stages of regional development that were 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 realize 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.

Three examples of interactions between spaces are discussed below, in connection with these different regional development stages.

New England Council, USA, 1920–1950

The New England Council case (Figure 4) exemplifies the importance of the knowledge and consensus spaces at the 'genesis' stage for initiating the innovation space. A transition from the consensus space to the knowledge

Box 4. Mechanisms for the creation of a consensus space.

1. *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 local innovation capacity. Similarly, the Knowledge Circle of Amsterdam meets regularly to formulate and propose 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).
2. *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 is the 1930s New England Council representing university, industry and government leadership in the region, which invented the contemporary format for the venture capital firm, building on 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 (Etzkowitz, 2002).
3. *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 when it faced 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 in which 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 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 multinational 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*).

space and further to the innovation space is identified in this case. The formation of the consensus space is exemplified by the creation of the Council by the Governors of the six New England states, by putting together resources to develop a renewal strategy for a region that had been in economic decline from the early 20th century due to the 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 an already strong knowledge space. The Council focused on enhancing the start-up phenomenon of firms emanating from the turn of the century from MIT and Harvard, involved with scientific instruments and the newly-emerging radio industry in the 1920s, and invented the venture capital firm to expand and intensify the creation of the innovation space.

Silicon Valley, California, in the mid-1990s

Silicon Valley in the mid-1990s exemplifies a transition from a knowledge space to a consensus space and then to an innovation space in the 'self-sustaining growth and

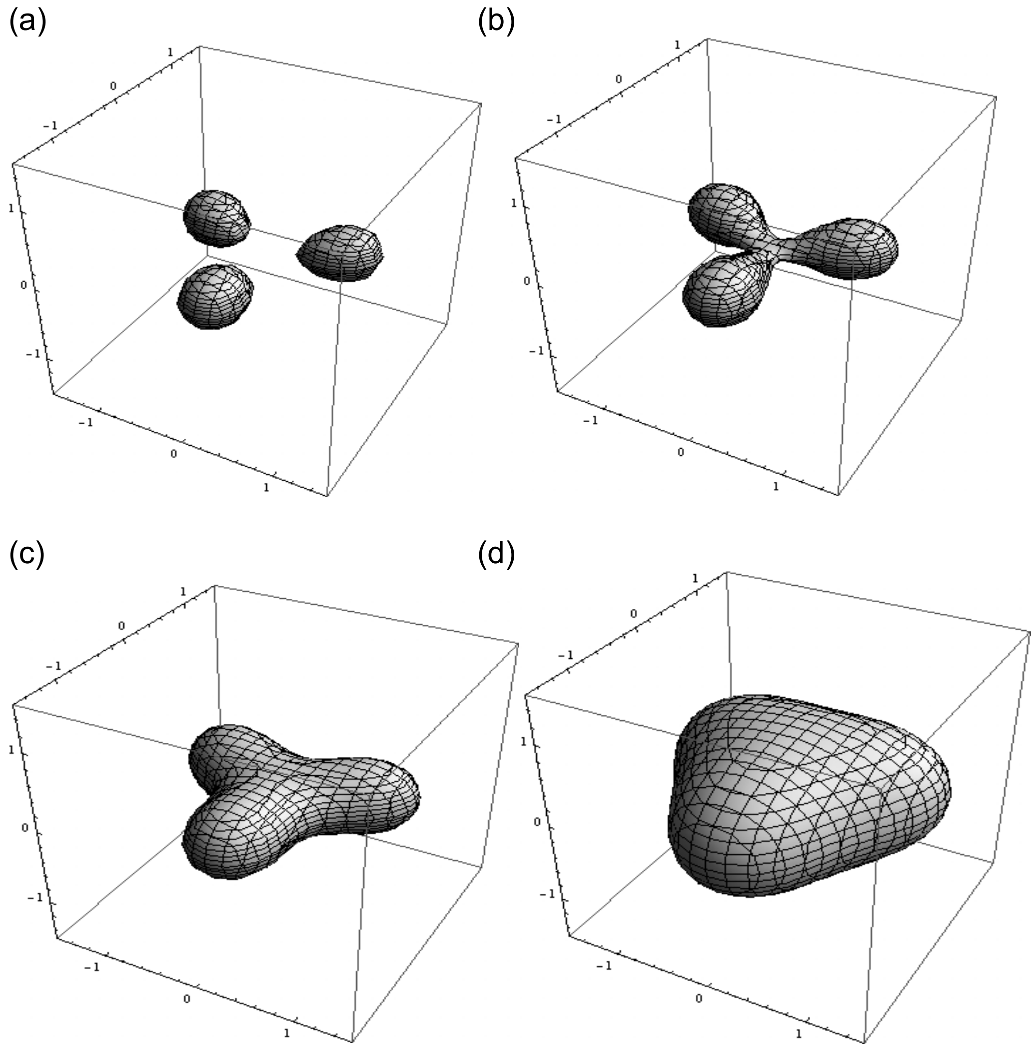

Figure 3. Interaction between the Triple Helix institutional spheres in the formation of a space: (a) institutional spheres apart – a *laissez-faire* regime; (b) institutional spheres getting closer together and starting to interact; (c) institutional spheres increasingly overlapping; and (d) institutional spheres overlapping in a balanced regime – formation of a 'stem cell space'.

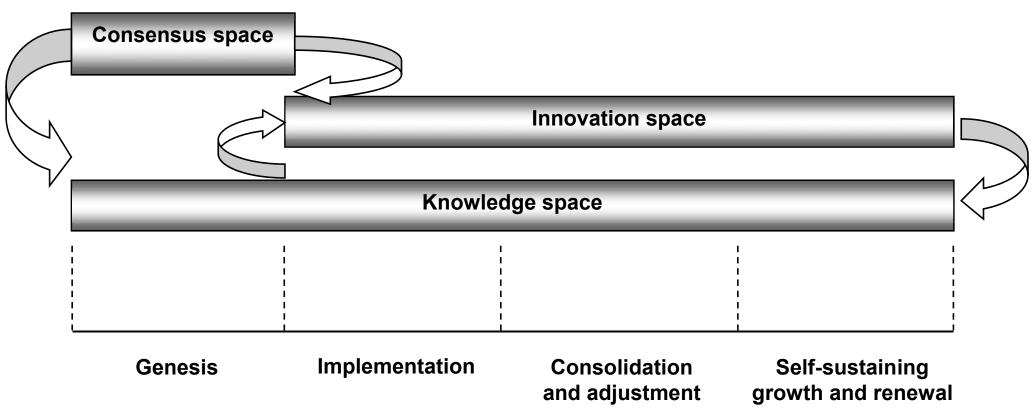

Figure 4. New England Council, 1920–1950.

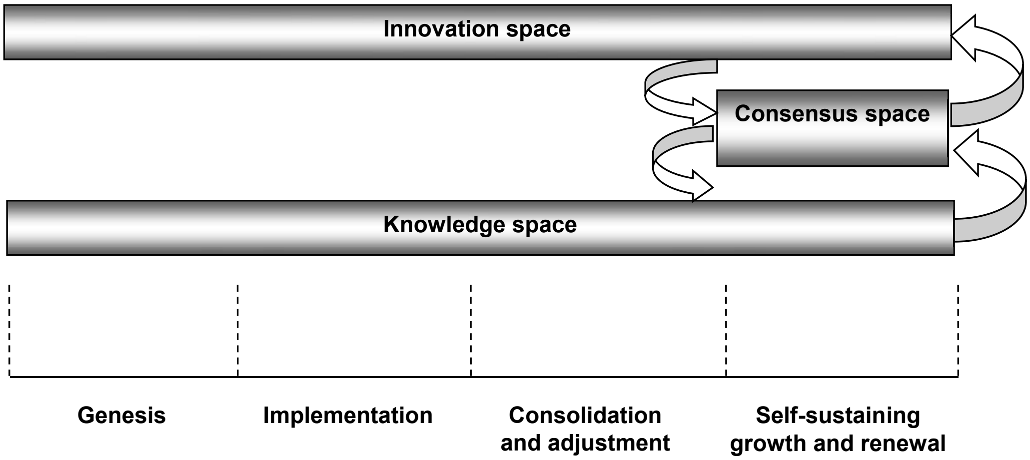

Figure 5. Silicon Valley in the mid-1990s.

renewal' phase (Figure 5). In the innovation space, many successful firms had either outgrown their university links or were spin-offs of an earlier 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 economic downturn of mid-1990s, 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 process, in the form of a series of open meetings focused on generating ideas for the future technological candidates, was initiated. A venture capital approach was adopted, with a few promising ideas, such as computer networking, winnowed from a larger collection (Miller, 1997).

Stockholm's Kista Science City, Sweden

The development of Stockholm's Kista Science City exemplifies how a successful consensus space further enhanced a knowledge-intensive and business-intensive platform created through the interplay between the knowledge and the innovation spaces (Figure 6). The history of Kista starts in the early 1970s when an Ericsson unit moved there, soon to be followed by IBM.[16] In the early 1980s, Stockholm's mayor envisaged the creation of an electronics centre which, once completed a few years later, attracted a significant number of electronics, engineering and computer science research institutes, academic research units and business firms and became an established ICT centre of national and international prestige – known also in the

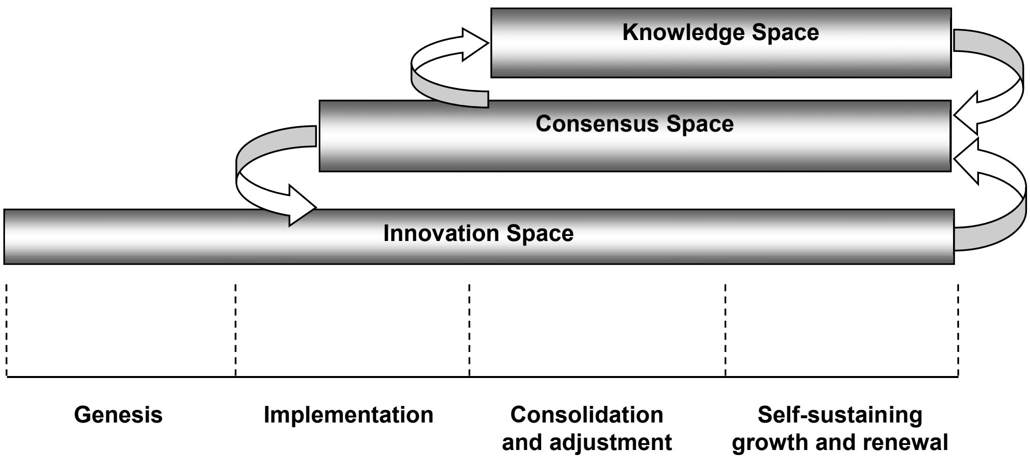

Figure 6. Stockholm's Kista Science City.

late 1980s as Sweden's Silicon Valley. In 2000 Stockholm's business community, academia and municipality saw the centre as the cornerstone for the foundation of Kista Science City. To implement this vision, Kista Science City AB was created and was soon ranked second by *Wired* magazine alongside similar developments in Boston and Israel. In 2002, the IT university was opened as a joint venture between the Royal Institute of Technology KTH and the University of Stockholm and this fuelled the formation of new business networks in Kista Science City's growth areas, especially ICT. Ericsson and many other businesses moved their offices to Kista and activities expanded to the entire region. In 2010, Kista Science City hosted more than 1,000 ICT companies and more than 5,000 ICT students and scientists – a high concentration of expertise, innovation and business opportunities within ICT that is unique in Sweden.

Policy relevance and implications and further research

This paper introduces the concept of Triple Helix systems as an analytical construct that organizes 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 that was hitherto lacking. In defining the components of Triple Helix systems, three important distinctions are made: between R&D and non-R&D innovators; between 'single-sphere' and 'multi-sphere' (hybrid) institutions; and between individuals and institutions. The relationships between components are synthesized into five main types: technology transfer, collaboration and conflict moderation, collaborative leadership, substitution and networking. The functions of Triple Helix systems are defined as a set of competencies that are achieved in what we call the 'knowledge, innovation and consensus spaces' and are designed to realize the Triple Helix systems' overall function of knowledge and innovation generation, diffusion and use. The formation of the spaces is envisioned as a two-step process: interaction of the Triple Helix institutional spheres and formation of a 'stem cell space', followed by the differentiation of the 'stem cell space' into a knowledge, innovation or a consensus space through the mobilization of actors, relations and resources and the creation of new institutional formats. The differentiation is triggered by specific environmental factors (such as local or regional needs), similar to stem cell differentiation induced by signalling proteins embedded in the cell surface.

The functioning of Triple Helix systems relies on the non-linear, diachronic transition from one space to another in varying directions, with one space catalysing the interaction between the others when they are present, or speeding up their development when they are weak or absent. The direction of transitions is related to different regional circumstances and development stages, which highlights the relevance of the Triple Helix systems to regional innovation strategies.

Policy relevance and policy implications

The Triple Helix systems approach offers a broad perspective for understanding the sources and development paths of innovation in different contexts. By introducing the Triple Helix model into a systems framework, a clearer, more fine-grained view can be achieved of:

- Key contributors to innovation and their interactions in correlation with their specific roles;
- Circulation of knowledge flows and resources within and among the knowledge, innovation and consensus spaces and identification of existing blockages or gaps; and
- New combinations of knowledge and resources that can be generated through the articulation between the spaces, generating a conceptual machinery for the advancement of innovation theory and practice.

An innovation strategy centred on the Triple Helix systems can be an attractive, novel perspective for policy makers, especially in regions that aim to pursue a knowledge-intensive development model and thus enhance their knowledge base and build 'steeples of excellence' from research themes with commercial potential and innovative firms that can realize that potential. Such regions can be found in both developed and developing countries, as shown by the recent 2011 categorisation of OECD regions using innovation-related variables that distinguishes between knowledge hubs, innovation production zones and non-S&T-driven regions (Ajmone Marsan and Maguire, 2011).

Various innovation policy approaches have been adopted at the regional level. Some European regions view innovation activities and the business innovation process as a network process, in which business and interactions with other partners play a significant part (Sternberg, 2000), while other European regions have focused on SME policy, on how SMEs innovate and to what extent they rely on other firms and organizations in their innovation activities (Asheim *et al*, 2003; Tödtling and Kaufmann, 2001). Several Nordic regions have adopted a cluster policy to explore similarities and differences between regional clusters of SMEs in different countries and develop social networking arrangements to boost and secure social capital and trust (Asheim *et al*, 2003). Several Canadian regions have also followed a cluster policy based on two main types of 'emerging' models of clusters:

(1) Regionally embedded and anchored regions where the local knowledge/science base represents a major generator of new, unique knowledge assets; and
(2) 'Entrepôt' regions where much of the knowledge base required for innovation and production is acquired through straightforward market transactions, often from non-local sources (Wolfe, 2003; Holbrook and Wolfe, 2002) (see details in Doloreux and Parto, 2004).

Some developing countries, where regional innovation policy is in its infancy, have only started to build their first regional innovation strategies under the coordination of the local regional innovation agencies or regional development agencies – for example, Izmir, the first region in Turkey to develop its own Regional Innovation Strategy (see Izmir Development Agency, 2012).

A Triple Helix systems-centred regional innovation strategy can be particularly relevant in the context of developing countries, because these countries, while seeking inspiration from the experience of developed countries, are also looking for novel models and solutions that could be better adapted to the realities and challenges of their own environment. A multitude of labels has emerged for these new innovation models, from 'pro-poor innovation' and 'grassroots innovation', to 'frugal innovation' and 'inclusive innovation', and so on. Irrespective of the name, common objectives of these models are the creation of new markets for innovative goods and services among those at the base of the pyramid, introduction of new technologies – particularly information and communication technologies, and creation of new contexts and new locations for innovation (UNIDO, 2003).

Developing countries committed to the transition to a knowledge-based development model also aim to develop a better research infrastructure, a highly qualified workforce and greater innovative potential of domestic enterprises, with a stronger competitive advantage. A shift from an exogenous regional development approach, based on relocation/attraction of firms from elsewhere, often subsidiaries or R&D centres of large multinationals, to an endogenous regional development approach, based on local factors – such as strong knowledge base, skilled labour services, proximity to knowledge sources, and regional technology strategies and plans – is in progress in many developing countries that want to increase their innovation potential.

New ways of achieving all of these objectives can be found from adopting a Triple Helix systems perspective, through consolidation of and articulation between the knowledge, innovation and consensus spaces. As we have shown earlier, when one space is weak or missing, the other spaces can accelerate its formation and development, creating new innovation opportunities. At the same time, the non-linear interactions and communications between the spaces also need to take into account the correlation of regional R&D and innovation policies with other policies (education, employment, trade, exports, fiscal). Going beyond a single region to the level of multi-regional collaboration is also key to creating a 'critical mass' of human and financial resources for broad-scope projects that involve higher risks and raise higher coordination challenges. These objectives resonate to a large extent with the European Union's new focus on 'research and innovation strategies for smart specialization'. The new policy requires national and regional authorities across Europe to identify unique characteristics and assets of each country and region, highlighting each region's competitive advantages, and rallying regional stakeholders and resources around an excellence-driven vision of their future, in order to use the EU's Structural Funds more efficiently and create synergies between different EU, national and regional policies, as well as between public and private investments (European Commission, 2013).

The policy implications arising from the adoption of a Triple Helix systems approach to innovation focus in particular on the measures that support the formation and consolidation of the Knowledge, Innovation and Consensus spaces. We have shown earlier that an important condition for creating and strengthening a 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. Policies to develop this 'critical mass' could concentrate on mapping regional/national innovation actors and analysing their evolution and future trends; understanding their priority-setting; the scope of operations (regional, national, international); and regional impact. Policy initiatives might also be directed at improving human resources for R&D in sciences and arts at national or regional level, improving the labour market for researchers, promoting better policies for employment, education and training, and immigration to attract world-class researchers, thus making research careers more available and attractive, especially for women and minorities, reducing 'brain drain' and improving 'brain gain'.

Similar policy actions are important in developing the innovation space: mapping of 'single-sphere' and 'multi-sphere' (hybrid) institutions and promoting policies that support their formation and activity; creation of seed funds; increased participation of industry and other private stakeholders in university and public research institutes' priority-setting; stimulation of the commercialization of university-generated technologies; fiscal measures to encourage the creation of innovative, high-tech start-ups; implementation of national and regional programmes to promote risk and venture capital funds; improved access to equity financing for research and innovation activities; and so on.

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 and collaborative leadership models and practices.

Further research

The analytical construct of Triple Helix systems we propose here still needs a better understanding of several issues, including the following.

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, because setting joint agendas often involves changes of vision, crossing organizational silos, thinking beyond the boundaries of a single institutional sphere, harmonizing institutional and individual objectives, resources, cultures, and so on. Such outcomes can be accelerated by top-down or bottom-up initiatives that not only need a favourable environment to reach fruition but also require policy measures that integrate innovation and entrepreneurship better within the larger socio-economic context, and especially research, education, labour market and development policies. Individual and collective Innovation Organizers whether in Ontario, Brainport Research Triangle (Leuven–Aachen–Eindhoven), the Lagos Innovation Council – among others – are key to overcoming institutional inertia.

Second, we also need to understand more about the growth of the spaces over time, especially in relation to the regional development stages, and about the functional requirements that are necessary for supporting each development stage. For example, we know that economic downturn and political crises are major catalysts in the creation of the consensus space, but how do consensus spaces get created in times of economic upturn? Or how can cross-institutional leadership arise in them where, to date, it has been conspicuously absent? A comparative analysis of the creation of consensus spaces under various regional conditions in different historical periods and stages of regional development will be most useful 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 organizational innovations is successful and when do these innovations impede development? What methodology should be developed for such an analysis? What gaps need to be filled with what type of organizational innovation and what elements need to be brought together to create organizational innovation? In the past, the venture capital model was created from such an analysis (Etzkowitz, 2002); what form should such analysis and solutions take in our present context? An initial step might be a synthesis of models that highlight the importance of creative leadership and counter-cyclical funding, targeted at innovation gaps and 'valleys of death' that emerge as a consequence of economic crises (Benner, 2012; Ranga and Etzkowitz, 2012).

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 rare.[17] 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 that have graduated from university incubators, monitored in some universities, could be a relevant indicator for the innovation space, while the number of collaborative projects involving Triple Helix actors, also often monitored in entrepreneurial universities, could become a good proxy for the consensus space.

Conclusions

To conclude, it is interesting to note that while 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 development that is often considered opaque and hidden, such insights encouraging initiatives and practices that carry the seeds of innovative developments.

Moreover, by providing a clearer view of innovation actors, knowledge and resources flows within and among the spaces and of existing blockages and gaps between them, the Triple Helix systems can help accelerate the transition from the low-risk, low-gain development model that is currently in place in many regions and countries and is conducive to slow, incremental innovation patterns with low economic returns, to a higher-risk, higher-gain development model that could favour more radical innovations and the accelerated creation of new markets, new growth opportunities, new jobs and new skills.

Notes

[1]An important part of this research has been published in special issues of refereed journals introducing papers presented at the Triple Helix conferences held since 1996 until present – see Appendix 1. Other examples of Triple Helix research can be found for example, in Rothaermel *et al*'s (2007) literature review that identified 173 academic articles published in peer-reviewed scholarly journals between1981–2005.

[2]See, for example, the VINN Excellence Centres and the VINNV⊿XT Programme of the Swedish Governmental Agency for Innovation Systems VINNOVA, or Brazil's 2004 Innovation Law that incentivizes the interaction between firms, public universities and research centres, or the European Union's Europe 2020 Strategy and its Innovation Union flagship initiative.

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

[4]These capabilities ensure the capacity of a system to make innovative choices of markets, products, technologies and organizational structure; to engage in entrepreneurial activity; to select key personnel and acquire key resources, including new competence; to organize and coordinate the resources and economic activities within the organization; to implement technologies and utilize them effectively in the market; to learn from success as well as failure, to read and interpret market signals and take appropriate actions, and to diffuse technology throughout the system (Carlsson *et al,* 2002, p 235).

[5]Carlsson (2003) refers to views of institutions as networks or organizations supporting technical innovation (Freeman, 1987; Nelson and Rosenberg, 1993), as rules or regimes that determine behaviour (Lundvall, 1992) and as institutional arrangements defining both regimes and organizations (Carlsson and Stankiewicz, 1991).

[6]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).

[7]For example, The Kitchen in New York City's Soho District invents 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 utilized as a source of ideas in the form of historical styles that may be reinterpreted in new ways with new materials or hybridized into new formats.

[8]See details on Brazil's 2004 Innovation Law at http://www.scidev.net/en/editorials/brazils-innovation-law-lessons-for-latin-america.html.

[9]See http://www.sfgate.com/news/article/Pixar-University-Thinking-Outside-The-Mouse-2611923.php.

[10]See http://www.eucys2012.eu/index.php?option=com_content&view=article&id=49&Itemid=36.

[11]See http://www.cisco.com/web/learning/netacad/academy/index.html.

[12]See http://appleinsider.com/articles/11/10/06/apple_university_revealed_as_plan_to_teach_executives_to_think_like_steve_jobs.

[13]The European Technology Platforms (ETPs) are industry-led multinational networks (36 ETPs in 2011) of various stakeholders who 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/).

[14]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).

[15]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 b2. The Cartesian equation of a Cassini oval is ((x-a)2 +y2)((x+a)2 +y2)=b4, 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 (see further details at http://mathworld.wolfram.com/CassiniOvals.html). 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.

[16]Selected from 'A History of Kista Science City' at: http://blog.naver.com/PostView.nhn?blogId=beyondui&logNo=130089515632&parentCategoryNo=96&viewDate=&currentPage=1&listtype=0

[17]For example, among the 25 indicators of the 2011 Innovation Union Scoreboard only one, public–private publications, captures the effect of collaboration between the university and industry spheres, while most of the others describe single-sphere effects (for example, 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, 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).

References

Ajmone Marsan, G., and Maguire, K. (2011), 'Categorisation of OECD regions using innovation-related variables', *OECD*

Regional Development Working Papers, 2011/03, OECD Publishing, http://dx.doi.org/10.1787/5 kg8bf42qv7k-en.
Almeida, M., Mello, J.M.C., and Etzkowitz, H. (2012), 'Social innovation in a developing country: invention and diffusion of the Brazilian cooperative incubator', *International Journal of Technology and Globalisation*, Vol 6, No 3, pp 206–224.
Amason, A.C. (1996), 'Distinguishing the effect of functional and dysfunctional conflict on strategic decision making: resolving a paradox for top management teams', *Academy of Management Journal*, Vol 39, pp 123–148.
Amason, A.C., and Sapienza, H.J. (1997), 'The effects of top management team size and interaction norms on cognitive and affective conflict', *Journal of Management*, Vol 23, pp 495–516.
Archer, D., and Cameron, A. (2009), *Collaborative Leadership – How to Succeed in an Interconnected World*, Butterworth-Heinemann, Oxford.
Arundel, A., Bordoy, C., and Kanerva, M. (2008), 'Neglected innovators: how do innovative firms that do not perform R&D innovate? – results of an analysis of the Innobarometer 2007 survey, No 215', *INNO-Metrics Thematic Paper*, European Commission, DG Enterprise, Brussels.
Asheim, B., Coenen, L., and Svensson-Henning, M. (2003), *Nordic SMEs and Regional Innovation Systems*, Nordisk Industrifond, Oslo.
Azagra-Caro, J.M., Carat, G., and Pontikakis, D. (2010), 'Geographical implications of the TH: inclining the columns to make the temple look straight, a first glance at monetary indicators on university–industry cooperation', *Research Evaluation*, Vol 19, No 2, pp 119–128.
Baldini, N. (2006), 'University patenting and licensing activity: a review of the literature', *Research Evaluation,* Vol 15, No 3, pp 197–207.
Benner, M. (2012), 'Innovation policy in hard times: lessons from the Nordic countries', *European Planning Studies*, Vol 20, No 9, pp 1455–1468.
Bergek, A., Jacobsson S., and Hekkert, M. (2007), 'Attributes in innovation systems: a framework for analysing energy system dynamics and identifying goals for system-building activities by entrepreneurs and policy makers', in Foxon, T., Kohler, J., and Oughton, C., eds, *Innovations for a Low Carbon Economy: Economic, Institutional and Management Approaches*, Edward Elgar, Cheltenham.
Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., and Rickne, A. (2008), 'Analyzing the functional dynamics of technological innovation systems: a scheme of analysis', *Research Policy*, Vol 37, No 3, pp 407–429.
Bianco,M., and Viscardi, N. (2008), 'Research organization in the university: the case of a leading Uruguayan group in basic science', *International Journal of Technology Management and Sustainable Development*, Vol 7, No 3, pp 237–249.
Bjerregaard, T. (2010), 'Industry and academia in convergence: micro-institutional dimensions of R&D collaboration', *Technovation*, Vol 30, No 2, pp 100–108.
Boardman, P.C. (2009), 'Government centrality to university–industry interactions: university research centers and the industry involvement of academic researchers', *Research Policy*, Vol 38, No 10, pp 1505–1516.
Booyens, I. (2011), 'Are small, medium- and micro-sized enterprises engines of innovation? – the reality in South Africa', *Science and Public Policy*, Vol 38, No 1, pp 67–78.
Breschi, S., and Malerba, F. (1997), 'Sectoral innovation systems: technological regimes, Schumpeterian dynamics and spatial boundaries', in Edquist, C., ed, *Systems of Innovation: Technologies, Institutions and Organizations,* Pinter/Cassell Academic, London and Washington.
Callon, M. (1992), 'The dynamics of techno-economic networks', in Coombs, R., Saviotti, P., and Walsh, V., eds, *Technological Change and Company Strategies: Economic and Sociological Perspectives,* Academic Press, London.
Campbell, E.G., Powers, J.B., Blumenthal, D., and Biles, B. (2004), 'Inside the Triple Helix: technology transfer and commercialization in the life sciences', *Health Affairs*, Vol 23, No 1, pp 64–76.
Carlsson, B., ed (1997), *Technological Systems and Industrial Dynamics*, Kluwer Academic Publishers, Boston/Dordrecht/London.
Carlsson, B. (1998), 'Innovation and knowledge spillovers: a systems cum evolutionary perspective', in Eliasson, G., and Green, C., eds, *Microfoundations of Economic Growth: A Schumpeterian Perspective*, University of Michigan Press, Ann Arbor, MI, pp 156–168.
Carlsson, B. (2003), 'Innovation systems: a survey of the literature from a Schumpeterian perspective', *paper for The Elgar Companion to Neo-Schumpeterian Economics*, downloaded 09 April 2012 from: http://faculty.weatherhead.case.edu/carlsson/documents/InnovationSystemsSurveypaper6.pdf.
Carlsson, B., Jacobsson, S., Holmén, M., and Rickne, A. (2002), 'Innovation systems: analytical and methodological issues', *Research Policy*, Vol 31, No 2, pp 233–245.
Carlsson, B., and Stankiewicz, R. (1991), 'On the nature, function, and composition of technological systems', *Journal of Evolutionary Economics*, No 1, pp 93–118.
Casas, R., de Gortari, R., and Santos, M.J. (2000), 'The building of knowledge spaces in Mexico: a regional approach to networking', *Research Policy*, Vol 29, No 2, pp 229–241.
Chrislip, D. (2002), *The Collaborative Leadership Fieldbook: A Guide for Citizens and Civic Leaders*, Jossey-Bass, San Francisco, CA.
Cohen, W.M., Levin, R.C., and Mowery, D.C. (1987), 'Firm size and R&D intensity: a re-examination', *Journal of Industrial Economics*, Vol 35, pp 543–563.
Cooke, P. (1996), *Regional Innovation Systems*, UCL Press, London.
Cooke, P. (2004), 'The molecular biology revolution and the rise of bioscience megacentres in North America and Europe', *Environment and Planning C: Government and Policy,* Vol 22, No 2, pp 161–177.
Currid, E. (2007), *The Warhol Economy*, Princeton University Press, Princeton, NJ.
Cusumano, M.A., and Elenkov, D. (1994), 'Linking international technology transfer with strategy and management: a literary commentary', *Research Policy*, Vol 23, No 2, pp 195–215.
David, P.A., and Foray, D. (2003), 'Economic fundamentals of the Knowledge Society', *Policy Futures in Education*, Vol 1, pp 20–49.
David, P.A., Foray, D., and Steinmueller, W.E. (1999), 'The research network and the new economics of science: from metaphors to organizational behaviours', in Gambardella, A., and Malerba, F., eds, *The Organisation of Innovative Activities in Europe,* Cambridge University Press, Cambridge.
De Clercq, D., Thongpapanl N., and Dimov, D. (2009), 'When good conflict gets better and bad conflict becomes worse: the role of social capital in the conflict–innovation relationship', *Journal of the Academy of Marketing Science*, Vol 37, pp 283–297.
Debackere, K. (2000), 'Managing academic R&D as a business at KU Leuven: context, structure and process', *R&D Management*, Vol 30, pp 323–328.
Debackere, K., and Veugelers, R. (2005), 'Improving industry science links through university technology transfer units: an analysis and a case', *Research Policy*, Vol 34, No 3, pp 321–342.
DeBresson, C., and Amesse, F. (1991), 'Networks of innovators: a review and introduction to the issue', *Research Policy*, Vol 20, No 5, pp 363–379.
Dolfsma, W., and Leydesdorff, L. (2009), 'Lock-in and break-out from technological trajectories: modelling and policy

implications', *Technological Forecasting and Social Change*, Vol 76, pp 932–941.
Doloreux, D., and Parto, S. (2004), 'Regional innovation systems: a critical review', *ERSA Conference Papers,* ersa04p56, see: http://www.ulb.ac.be/soco/asrdlf/documents/RIS_Doloreux-Parto_000.pdf
Doloreux, D., and Parto, S. (2005), 'Regional innovation systems: current discourse and unresolved issues', *Technology in Society*, Vol 27, pp 133–153.
Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., and Soete, L., eds (1998), *Technology and Economic Theory,* Pinter, London.
Edquist, C. (1997), 'Systems of innovation approaches: their emergence and characteristics', in Edquist, C., ed, *Systems of Innovation: Technologies, Institutions and Organizations*, Pinter, London.
Edquist, C. (2005), 'Systems of innovation: perspectives and challenges', in Fagerberg, J., Mowery, D.C., and Nelson, R.R., eds, *The Oxford Handbook of Innovation*, Oxford University Press, New York, pp 181–208.
Etzkowitz, H. (1993), 'Technology transfer: the second academic revolution', *Technology Access Report,* No 6, pp 7–9.
Etzkowitz, H. (2002*), MIT and the Rise of Entrepreneurial Science*, Routledge, London.
Etzkowitz, H. (2003), Innovation in innovation: the Triple Helix of university–industry–government relations', *Social Science Information*, Vol 42, pp 293–338.
Etzkowitz, H. (2008), *The Triple Helix: University–Industry–Government Innovation in Action*, Routledge, London.
Etzkowitz, H. (2012), 'Triple Helix clusters: boundary permeability at university–industry–government interfaces as a regional innovation strategy', *Environment and Planning C: Government and Policy*, Vol 30, No 5, pp 766–779.
Etzkowitz, H., and Klofsten, M. (2005), 'The innovating region: towards a theory of knowledge-based regional development', *R&D Management*, Vol 35, pp 243–255.
Etzkowitz, H., and Leydesdorff, L. (1995), 'The Triple Helix: university–industry–government relations: a laboratory for knowledge-based economic development', *EASST Review*, Vol 14, pp 14–19.
Etzkowitz, H., and Leydesdorff, L. (1998), 'The endless transition: a "triple helix" of university–industry–government relations', *Minerva*, Vol 36, pp 203–208.
Etzkowitz, H., and Leydesdorff, L. (2000), 'The dynamics of innovation: from national systems and "Mode 2" to a Triple Helix of university–industry–government relations', *Research Policy,* Vol 29, No 2, pp 109–123.
Etzkowitz, H., and Raiken, L. (1980), 'Artists' social movements of the 1960's and 70's: from protest to institution-formation', *paper presented at Eastern Sociological Society Thematic Session*, Boston, MA, distributed by ERIC Clearinghouse, ERIC No ED186326, see: http://www.eric.ed.gov/.
Etzkowitz, H., and Schaflander, G. (1969), *Ghetto Crisis*, Little Brown, Boston, MA.
Etzkowitz, H., Mello, J.M.C., and Almeida, M. (2005), 'Towards "meta-innovation" in Brazil: the evolution of the incubator and the emergence of a Triple Helix', *Research Policy*, Vol 34, No 4, pp 411–424.
Etzkowitz, H., Ranga, M., Benner, M., Guaranys, L., Maculan, A.M., and Kneller, R. (2008), 'Pathways to the entrepreneurial university: towards a global convergence', *Science and Public Policy*, Vol 35, pp 1–15.
European Commission (2013), 'Research and innovation strategies for smart specialisation', see: http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/smart_specialisation_en.pdf.
Feldman, M.P., and Desrochers, P. (2004), 'Truth for its own sake: academic culture and technology transfer at Johns Hopkins University', *Minerva*, Vol 42, No 2, pp 105–126.
Finkelstein, S., and Mooney, A.C. (2003), 'Not the usual suspects: how to use board process to make boards better', *Academy of Management Executive*, Vol 17, No 2, pp 101–113.
Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, Pinter, London.
Freeman, C. (1988), 'Japan: a new national innovation system?', in Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., and Soete, L., eds, *Technical Change and Economic Theory*, Pinter, London.
Freeman, C. (1991), 'Networks of innovators: a synthesis of research issues', *Research Policy*, Vol 20, No 5, pp 499–514.
Freeman, C., and Lundvall, B.-Å., eds (1988), *Small Countries Facing the Technological Revolution*, Pinter, London.
Freiberger, P., and Swaine, M. (2000), *Fire in the Valley: The Making of the Personal Computer*, McGraw-Hill, New York.
Furman, J.L., and MacGarvie, M. (2009), 'Academic collaboration and organizational innovation: the development of research capabilities in the US pharmaceutical industry, 1927–1946', *Industrial and Corporate Change*, Vol 18, No 5, pp 929–961.
Galende, J., and de la Fuente, J.M. (2003), 'Internal factors determining a firm's innovative behaviour', *Research Policy*, Vol 32, No 5, pp 715–736.
Galende, J., and Suarez Gonzales, I. (1999), 'A resource-based analysis of the factors determining a firm's R&D activities', *Research Policy*, Vol 28, No 8, pp 891–905.
Gebhardt, C. (2012), 'The entrepreneurial state: the German entrepreneurial regions program as an attenuator for the financial crisis', *European Planning Studies*, Vol 20, No 9, pp 1469–1482.
Geuna, A., and Nesta, L.J.J. (2006), 'University patenting and its effects on academic research: the emerging European evidence', *Research Policy*, Vol 35, No 6, pp 790–807.
Geuna, A., and Rossi, F. (2011), 'Changes to university IPR regulations in Europe and the impact on academic patenting', *Research Policy,* Vol 40, No 8, pp 1068–1076.
Gibney, J., Copeland, S., and Murie, A. (2009), 'Towards a "new" strategic leadership of place for the knowledge-based economy', *Leadership*, Vol 5, pp 5–23.
Goldstein, H.A. (2010), 'The "entrepreneurial turn" and regional economic development mission of universities', *Annals of Regional Science*, Vol 44, No 1, pp 83–109.
Hamilton, W.B. (1966), 'The research triangle of North Carolina: a study in leadership for the common weal', *South Atlantic Quarterly*, Vol 65, pp 254–278.
Heerwagen, J., Kelly, K., and Kampschroer, K. (2010), 'The changing nature of organizations, work and workplace', downloaded on 08 April 2013 from: http://www.wbdg.org/resources/chngorgwork.php.
Heidenreich, M. (2009), 'Innovation patterns and location of European low- and medium-technology industries', *Research Policy*, Vol 38, No 3, pp 483–494.
Hekkert, M., Suurs, R.A.A., Negro, S., Kuhlmann, S., and Smits, R. (2008), 'Attributes of innovation systems: a new approach for analysing technological change', *Technological Forecasting and Social Change,* Vol 74, pp 413–432.
Holbrook, A., and Wolfe, D. (2002), *Knowledge, Clusters and Regional Innovation: Economic Development in Canada,* Queen's School of Policy Studies, Kingston, Ontario.
Huggins, R. (2008), 'Universities and knowledge-based venturing: finance, management and networks in London', *Entrepreneurship and Regional Development*, Vol 20, No 2, pp 185–206.
Inzelt, A. (2004), 'The evolution of university–industry–government relationships during transition', *Research Policy*, Vol 33, No 6–7, pp 975–995.
Iversen, E.J., Gulbrandsen, M., and Klitkou, A. (2007), 'A baseline for the impact of academic patenting legislation in Norway', *Scientometrics*, Vol 70, No 2, pp 393–414.

Izmir Development Agency (2012), *Izmir Regional Innovation Strategy*, see: http://www.izka.org.tr/en/izmirde-yatirim/izmirde-yatirim-ortami/izmir-kalkinma-ajansi/.
Jehn, K.A. (1995), 'A multi-method examination of the benefits and detriments of intra-group conflict', *Administrative Science Quarterly*, Vol 40, pp 256–282.
Jehn, K.A., and Mannix, E.A. (2001), 'The dynamic nature of conflict: a longitudinal study of intra-group conflict and group performance', *Academy of Management Journal*, Vol 44, No 238–251.
Jensen, M.B., Johnson, B., Lorenz, E., and Lundvall B.A. (2007), 'Forms of knowledge and modes of innovation', *Research Policy*, Vol 36, No 5, pp 680–693.
Kaufmann, A., and Tödtling, F. (2001), 'Science–industry interaction in the process of innovation: the importance of boundary-crossing between systems', *Research Policy*, Vol 30, No 5, pp 791–804.
Klofsten, M., Jones-Evans, D., and Schärberg, C. (1999), 'Growing the Linköping Technopole: longitudinal study of the Triple Helix development in Sweden', *Journal of Technology Transfer*, Vol 24, No 2–3, pp 125–138.
Konde, V. (2004), 'Internet development in Zambia: a Triple Helix of government–university–partners', International Journal of Technology Management, Vol 27, No 5, pp 440–451.
Kruss, G. (2008), 'Balancing old and new organisational forms: changing dynamics of government, industry and university interaction in South Africa', *Technology Analysis and Strategic Management* Vol 20, No 6, pp 667–682.
Kuhlmann, S. (2001), 'Future governance of innovation policy in Europe: three scenarios', *Research Policy*, Vol 30, No 6, pp 953–976.
Kwon, K.S., Park, H.W., So, M., and Leydesdorff, L. (2012), 'Has globalization strengthened South Korea's national research system? – national and international dynamics of the Triple Helix of scientific co-authorship relationships in South Korea', *Scientometrics*, Vol 90, No 1, pp 163–176.
Lawton Smith, H., and Bagchi-Sen Sharmistha, S. (2010), 'Triple Helix and regional development: a perspective from Oxfordshire in the UK', *Technology Analysis and Strategic Management*, Vol 22, pp 805–818.
Lee, M.S., and Peterson, S.J. (2000), 'Culture, entrepreneurial orientation and global competitiveness', *Journal of World Business*, Vol 35, pp 401–416.
Leydesdorff, L. (1996), 'Luhmann's sociological theory: its operationalisation and future perspectives', *Social Science Information*, Vol 35, pp 283–306.
Leydesdorff, L. (1997), 'The new communication regime of university–industry–government relations', in Etzkowitz, H., and Leydesdorff, L., eds, *Universities and the Global Knowledge Economy: A Triple Helix of University–Industry–Government Relations*, Cassell Academic, London.
Leydesdorff, L. (2000), 'The Triple Helix: an evolutionary model of innovations', *Research Policy*, Vol 29, No 2, pp 243–255.
Leydesdorff, L. (2003), 'The mutual information of university–industry–government relations: an indicator of the Triple Helix dynamics', *Scientometrics*, Vol 58, pp 445–467.
Leydesdorff, L. (2006), *The Knowledge-Based Economy: Modeled, Measured, Simulated*, Universal Publishers, Boca Raton, FL.
Leydesdorff, L. (2008), 'Configurational information as potentially negative entropy: the Triple Helix model', *Entropy*, Vol 10, pp 391–410.
Leydesdorff, L., and Etzkowitz, H. (1996), 'Emergence of a Triple Helix of university–industry–government relations', *Science and Public Policy*, Vol 23, pp 279–86.
Leydesdorff, L., and Etzkowitz, H. (1998), 'The Triple Helix as a model for innovation studies', *Science and Public Policy*, Vol 25, pp 195–203.
Leydesdorff, L., and Meyer, M. (2006), 'Triple Helix indicators of knowledge-based innovation systems: introduction to the Special Issue', *Research Policy*, Vol 35, No 10, pp 1441–1449.
Leydesdorff, L., and Meyer, M. (2010), 'The decline of university patenting and the end of the Bayh-Dole effect', *Scientometrics*, Vol 83, No 2, pp 355–362.
Leydesdorff, L., Dolfsma, W., and Van der Panne, G. (2006), 'Measuring the knowledge base of an economy in terms of Triple Helix relations among technology, organization and territory', *Research Policy*, Vol 35, No 2, pp 181–199.
Lowe, C.U. (1982), 'The Triple Helix – NIH, industry, and the academic World', *Yale Journal of Biology and Medicine*, Vol 55, pp 239–246.
Luhmann, N. (1975), 'Systemtheorie, Evolutionstheorie und Kommunikationstheorie', *Soziologische Gids,* Vol 22, No 3, pp 154–168.
Luhmann, N. (1984), *Soziale Systeme: Grundriß einer allgemeinen Theorie*, Suhrkamp, Frankfurt, published in English (1995), as *Social Systems*, Stanford University Press, Stanford, CA.
Luna, M., and Tirtido, R. (2008), 'Business associations and their contribution to knowledge networks in Mexico', *International Journal of Technology Management and Sustainable Development*, Vol 7, No 3, pp 251–264.
Lundvall, B.-Å. (1988), 'Innovation as an interactive process: from user–producer interaction to national systems of innovation', in Dosi, G., ed, *Technology and Economic Theory*, Pinter, London.
Lundvall, B.-Å., ed. (1992), *National Systems of Innovation*, Pinter, London.
Malerba, F. (2002), 'Sectoral systems of innovation and production', *Research Policy*, Vol 31, No 2, pp 247–264.
Maskell, P., and Malmberg, A. (1997), 'Towards an explanation of regional specialization and industry agglomeration', *European Planning Studies*, Vol 5, pp 25–41.
Mason, C., and Harrison, R. (1992), 'Strategy for closing the small firms finance gap', in Caley, D., Leigh, R., and Smallbone, D., eds, *Small Enterprise Development*, Paul Chapman, London.
Mello, J.M.C., and Alves Rocha, F.C. (2004), 'Networking for regional innovation and economic growth: the Brazilian Petropolis technopole', International Journal of Technology Management, Vol 27, No 5, pp 488–497.
Mets, T. (2010), 'Entrepreneurial business model for classical research university', *Inzinerine Ekonomika – Engineering Economics*, Vol 21, No 1, pp 80–89.
Mets, T., Andrijevskaja, J., and Varblane, U. (2008), 'The role of the University of Tartu in the development of entrepreneurship in the region of South Estonia', *International Journal of Entrepreneurship and Innovation Management*, Vol 8, No 6, pp 648–664.
Meyer, M. (2006), 'Are patenting scientists the better scholars? – an exploratory comparison of inventor-authors with their non-inventing peers in nano-science and technology', *Research Policy*, Vol 35, No 10, pp 1646–1662.
Miller, W. (1997), 'Stanford University Business School and Joint Venture Silicon Valley', verbal interview with Henry Etzkowitz.
Nelson, R.R., ed. (1993), *National Innovation Systems*, Oxford University Press, New York.
Nelson, R.R., and Rosenberg, N. (1993), 'Technical innovation and national systems', in Nelson, R.R., ed, *National Innovation Systems*, Oxford University Press, Oxford, pp 3–21.
Parsons, T. (1951), *The Social System,* The Free Press, New York.
Parsons, T., and Shils, E., eds (1951), *Toward a General Theory of Action,* Harvard University Press, Cambridge, MA.
Parsons, T., and Smelser N.J. (1956), *Economy and Society,* Routledge and Kegan Paul, London.
Pelled, L.H., Eisenhardt, K.M., and Xin, K.R. (1999), 'Exploring the black box: an analysis of work group diversity, conflict

and performance', *Administrative Science Quarterly*, Vol 44, pp 1–28.
Powell, W.W. (1990), 'Neither market nor hierarchy: network forms of organization', *Research in Organizational Behavior*, Vol 12, pp 295–336.
Ranga, L.M., Miedema, J.L., and Jorna, R.J. (2008), 'Enhancing the innovative capacity of small firms through Triple Helix interactions: challenges and opportunities', *Technology Analysis and Strategic Management*, Vol 20, pp 697–716.
Ranga, M., and Etzkowitz, H. (2012), 'Great expectations: an innovation solution to the contemporary economic crisis', *European Planning Studies*, Vol 20, No 9, pp 1429–1438.
Ranga, M., Perälampi, J., and Kansikas, J. (2013), 'University brainpower unchained: a comparative analysis of university–business cooperation in the US and Finland', *Entrepreneurship Theory and Practice* (forthcoming).
Rodrigues, C., and Melo, A. (2010), 'The Triple Helix Model as inspiration for local development policies: an experience-based perspective', *Working Paper SACSJP*, University of Aveiro, Aveiro.
Rothaermel, F.T., Agung, S.D., and Jiang, L. (2007), 'University entrepreneurship: a taxonomy of the literature', *Industrial and Corporate Change*, Vol 16, No 4, pp 691–791.
Ruuska, I., and Teigland, R. (2009), 'Ensuring project success through collective competence and creative conflict in public–private partnerships: a case study of Bygga Villa, a Swedish Triple Helix e-government initiative', *International Journal of Project Management*, Vol 27, No 4, pp 323–334.
Sábato, J., and Mackenzi, M. (1982), *La Producción de Technologia: Autónoma o Transnacional*, Nueva Imagen, Mexico.
Saenz, T.W. (2008), 'The path to innovation: the Cuban experience', *International Journal of Technology Management and Sustainable Development*, Vol 7, No 3, pp 205–221.
Saul, M.H., Gershman, J., and Grossman, A. (2011), 'Cornell wins contest for city tech campus', *The Wall Street Journal*, 19 December 2011, see: http://online.wsj.com/article/SB10001424052970204879004577107190097493490.html.
Schumpeter, J.A. (1942), *Capitalism, Socialism and Democracy*, George Allen and Unwin, New York.
Schumpeter, J. (1951), *Essays on Economic Topics*, Kennikat Press, Port Washington, New York.
Schutz, A. (1964), *Collected Papers II: Studies in Social Theory*, Brodersen, A., ed, Martinus Nijhoff, Dordrecht.
Shannon, C.E. (1948), 'A mathematical theory of communication', *Bell System Technical Journal*, Vol 27, pp 379–423 and pp 623–656.
Simmel, G. (1922 [1955]), *Conflict and the Web of Group Affiliations*, Wolff. K, translator and ed, Free Press, Glencoe, IL.
Steinmueller, W.E. (1994), 'Basic research and industrial innovation', in Dodgson, M., and Rothwell, R., eds, *The Handbook of Industrial Innovation,* Edward Elgar, Cheltenham, pp 54–66.
Sternberg, R. (2000), 'Innovation networks and regional development: evidence from the European Regional Innovation Survey (ERIS)', *European Planning Studies*, Vol 8, No 4, pp 389–407.
Storper, M. (1997), *The Regional World*, The Guilford Press, New York.
Svensson, P., Klofsten, M., and Etzkowitz, H. (2012), 'The Norrkoping way: a knowledge-based strategy for renewing a declining industrial city', *European Planning Studies*, Vol 20, No 4, pp 505–525.
Thwaites, A., and Wynarczyk, P. (1996), 'The economic performance of innovative small firms in the South East region and elsewhere in the UK', *Regional Studies*, Vol 30, pp 135–149.
Tijssen, R.J.W. (2006), 'Universities and industrially relevant science: towards measurement models and indicators of entrepreneurial orientation', *Research Policy*, Vol 35, No 10, pp 1569–1585.
Tijssen, R.J.W. (2012), 'Co-authored research publications and strategic analysis of public–private collaboration', *Research Evaluation*, Vol 21, No 3, pp 204–215.
Tödtling, F., and Kaufmann, A. (2001), 'The role of the region for innovation activities of SMEs', *European Urban and Regional Studies*, Vol 8, No 3, pp 203–215.
UNIDO (2003), 'Strategies for regional innovation systems: learning transfer and applications', *Policy Paper*, see http://www.unido.org/fileadmin/user_media/Publications/Pub_free/Strategies_for_regional_innovation_systems.pdf.
Van Dyne, L., and Saavedra, R. (1996), 'A naturalistic minority influence experiment: effects on divergent thinking, conflict and originality in work-groups', *British Journal of Social Psychology*, Vol 35, No 1, pp 151–168.
Van Looy, B., Magerman, T., and Debackere, K. (2007), 'Developing technology in the vicinity of science: an examination of the relationship between science intensity (of patents) and technological productivity within the field of biotechnology', *Scientometrics*, Vol 70, No 2, pp 441–458.
Wang, J., and Shapira, P. (2012), 'Partnering with universities: a good choice for nanotechnology start-up firms?', *Small Business Economics*, Vol 38, No 2, pp 197–215.
Wolfe, D. (2003) *Clusters Old and New: The Transition to a Knowledge Economy in Canada's Regions*, Queen's School of Policy Studies, Kingston, Ontario.
Wong, P.K. (2007), 'Commercializing biomedical science in a rapidly changing "Triple Helix" nexus: the experience of the National University of Singapore', *Journal of Technology Transfer*, Vol 32, No 4, pp 367–95.

Appendix 1

Journal special issues based on papers presented at Triple Helix conferences (1996–2011)

Journal reference	Special Issue name and guest editors
Science and Public Policy Vol 24, No 1 (1997).	'Science policy dimensions of the Triple Helix of university–industry–government relations' (Henry Etzkowitz and Loet Leydesdorff).
Minerva Vol 36 , No 3 (1998)	'The endless transition' (Henry Etzkowitz and Loet Leydesdorff).
Industry and Higher Education Vol 12, No 4 (1998).	'A Triple Helix of university–industry–government relations' (Henry Etzkowitz and Loet Leydesdorff).
Science and Public Policy Vol 25, No 6 (1998).	'The Triple Helix of innovation' (Henry Etzkowitz and Loet Leydesdorff).
Journal of Technology Transfer Vol 24, No 2–3 (1999).	'University–industry–government relations: a Triple Helix' (Henry Etzkowitz and Loet Leydesdorff).
Research Policy Vol 29, No 2 (2000).	'Triple Helix' (Henry Etzkowitz and Loet Leydesdorff).
Science and Public Policy Vol 27, No 4 (2000).	'The Eastern European transition' (Henry Etzkowitz and Karel Muller).
Science, Technology & Human Values Vol 28, No 1 (2003).	
International Journal of Technology Management & Sustainable Development Vol 7, No 3 (2008).	'Knowledge for innovation in Latin America' (Jose Manoel Carvalho de Mello).
Scientometrics Vol 58, No 2 (2003).	'The Triple Helix of university–industry–government relations' (Loet Leydesdorff and Martin Meyer).
Science and Public Policy Vol 30, No 4 (2003).	'Boundary organisations in science: from discourse to construction' (Tomas Hellström and Merle Jacob).
International Journal of Technology Management Vol 27, No 5 (2004).	
Technology Analysis and Strategic Management, Vol 17, No 1 (2005).	'The management of innovation revisited: strategy, control and culture' (Markus Pohlman, Christiane Gebhardt and Henry Etzkowitz).
Research Policy Vol 35, No 10 (2006).	'Triple Helix indicators of knowledge-based innovation systems' (Loet Leydesdorff and M. Meyer).
Scientometrics Vol 70, No 2 (2007).	'The scientometrics of a Triple Helix of university–industry–government relations' (Loet Leydesdorff and Martin Meyer).
Science and Public Policy Vol 35, No 9 (2008).	'Building the entrepreneurial university: a global perspective' (Henry Etzkowitz and Chunyan Zhou).
Industry and Higher Education Vol 24, No 3 (2010).	'Knowledge exchange and the Third Mission of universities' (Girma Zawdie and John Edmondson).
Journal of Technology Management and Innovation Vol 5, No 1 (2010).	'Gender dimension in technology, innovation and entrepreneurship' (Marina Ranga and Henry Etzkowitz).
Technology Analysis and Strategic Management Vol 22, No 7 (2010).	'The Triple Helix and innovation systems (Girma Zawdie and Loet Leydesdorff).
Science and Public Policy Vol 38, No 1 (2011).	'Triple Helix in the context of developing countries' (Mohammed Saad and Girma Zawdie).
Industry and Higher Education Vol 27, No 4 (2013)	'Innovation policy as a concept for developing economies: renewed perspectives on the Triple Helix system' (Dessy Irawati and Christiane Gebhardt).
Social Science Information Vol 52, No 4 (2013)	'Silicon Valley: global model or unique anomaly?' (Henry Etzkowitz).