Innovation, Technology, and Knowledge Management

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Multiple Helix Ecosystems for Sustainable Competitiveness

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Series Foreword

The Springer book series *Innovation, Technology, and Knowledge Management* was launched in March 2008 as a forum and intellectual, scholarly "podium" for global/ local, transdisciplinary, transsectoral, public-private, and leading/ "bleeding"-edge ideas, theories, and perspectives on these topics.

The book series is accompanied by the Springer *Journal of the Knowledge Economy*, which was launched in 2009 with the same editorial leadership.

The series showcases provocative views that diverge from the current "conventional wisdom," that are properly grounded in theory and practice, and that consider the concepts of ***robust competitiveness***,[1] ***sustainable entrepreneurship***,[2] and ***democratic capitalism***,[3] central to its philosophy and objectives. More specifically, the aim of this series is to highlight emerging research and practice at the dynamic

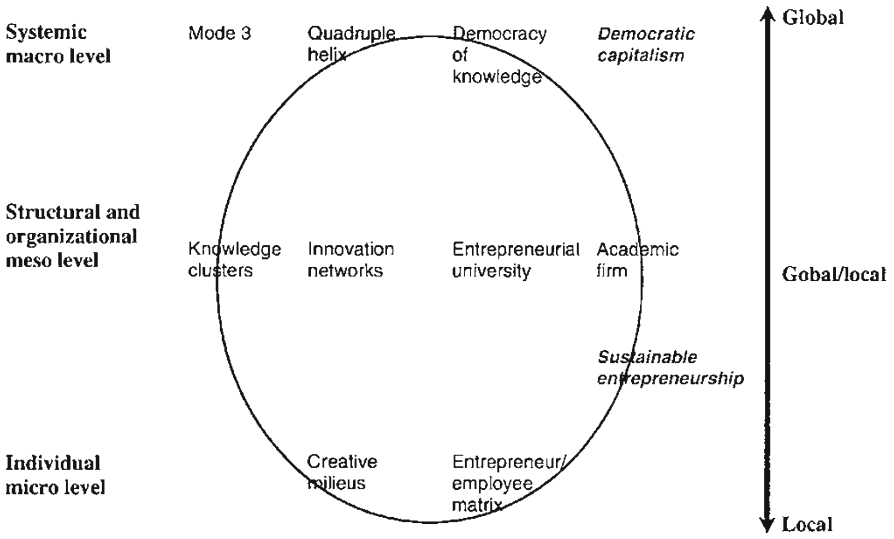
[1] We define *sustainable entrepreneurship* as the creation of viable, profitable, and scalable firms. Such firms engender the formation of self-replicating and mutually enhancing innovation networks and knowledge clusters (innovation ecosystems), leading toward robust competitive- ness (E.G. Carayannis, *International Journal of Innovation and Regional Development* 1(3), 235–254, 2009).

[2] We understand *robust competitiveness* to be a state of economic being and becoming that avails systematic and defensible "unfair advantages" to the entities that are part of the economy. Such competitiveness is built on mutually complementary and reinforcing low-, medium- and high-technology and public and private sector entities (government agencies, private firms, universities, and nongovernmental organizations) (E.G. Carayannis, *International Journal of Innovation and Regional Development* 1(3), 235–254, 2009).

[3] The concepts of *robust competitiveness and sustainable entrepreneurship* are pillars of a regime that we call "*democratic capitalism*" (as opposed to "popular or casino capitalism"), in which real opportunities for education and economic prosperity are available to all. especially—but not only—younger people. These are the direct derivative of a collection of top-down policies as well as bottom-up initiatives (including strong research and development policies and funding, but going beyond these to include the development of innovation networks and knowledge clusters across regions and sectors) (E.G. Carayannis and A. Kaloudis. *Japan Economic Currents*, p. 6–10, January 2009).

intersection of these fields, where individuals, organizations, industries, regions, and nations are harnessing creativity and invention to achieve and sustain growth.

Books that are part of the series explore the impact of innovation at the "macro" (economies, markets), "meso" (industries, firms), and "micro" levels (teams, individuals), drawing from such related disciplines as finance, organiza- tional psychology, research and development, science policy, information systems, and strategy, with the underlying theme that for innovation to be useful it must involve the sharing and application of knowledge.



Some of the key anchoring concepts of the series are outlined in the figure below and the definitions that follow (all definitions are from E.G. Carayannis and D.F.J. Campbell, *International Journal of Technology Management*, 46, 3–4, 2009).

Conceptual profile of the series Innovation, Technology, and Knowledge Management

- The "Mode 3" Systems Approach for Knowledge Creation, Diffusion, and Use: "Mode 3" is a multilateral, multinodal, multimodal, and multilevel systems approach to the conceptualization, design, and management of real and virtual, "knowledge-stock" and "knowledge-flow," modalities that catalyze, accelerate, and support the creation, diffusion, sharing, absorption, and use of cospecialized knowledge assets. "Mode 3" is based on a system-theoretic perspective of socio-economic, political, technological, and cultural trends and conditions that shape the coevolution of knowledge with the "knowledge-based and knowledge-driven, global/local economy and society."

- Quadruple Helix: Quadruple helix, in this context, means to add to the triple helix of government, university, and industry a "fourth helix" that we identify as the "media-based and culture-based public." This fourth helix associates with "media," "creative industries," "culture," "values," "life styles," "art," and perhaps also the notion of the "creative class."
- Innovation Networks: Innovation networks are real and virtual infrastructures and infratechnologies that serve to nurture creativity, trigger invention, and catalyze innovation in a public and/or private domain context (for instance, government–university–industry public–private research and technology devel- opment coopetitive partnerships).
- Knowledge Clusters: Knowledge clusters are agglomerations of cospecialized, mutually complementary, and reinforcing knowledge assets in the form of "knowledge stocks" and "knowledge flows" that exhibit self-organizing, learning-driven, dynamically adaptive competences and trends in the context of an open systems perspective.
- Twenty-First Century Innovation Ecosystem: A twenty-first century innovation ecosystem is a multilevel, multimodal, multinodal, and multiagent system of systems. The constituent systems consist of innovation metanetworks (networks of innovation networks and knowledge clusters) and knowledge metaclusters (clusters of innovation networks and knowledge clusters) as building blocks and organized in a self-referential or chaotic fractal knowledge and innovation architecture (Carayannis 2001), which in turn constitute agglomerations of human, social, intellectual, and financial capital stocks and flows as well as cultural and technological artifacts and modalities, continually coevolving, cospecializ- ing, and cooperating. These innovation networks and knowledge clusters also form, reform, and dissolve within diverse institutional, political, technological, and socioeconomic domains, including government, university, industry, and nongovernmental organizations and involving information and communication technologies, biotechnologies, advanced materials, nanotech- nologies, and next- Generation energy technologies.

Who is this book series published for? The book series addresses a diversity of audiences in different settings:

1. *Academic communities*: Academic communities worldwide represent a core group of readers. This follows from the theoretical/conceptual interest of the book series to influence academic discourses in the fields of knowledge, also carried by the claim of a certain saturation of academia with the current concepts and the postulate of a window of opportunity for new or at least additional concepts. Thus, it represents a key challenge for the series to exercise a certain impact on discourses in academia. In principle, all academic communities that are interested in knowledge (knowledge and innovation) could be tackled by the book series. The interdisciplinary (transdisciplinary) nature of the book series underscores that the scope of the book series is not limited a priori to a specific basket of disciplines. From a radical viewpoint, one could create the hypothesis that there is no discipline where knowledge is of no importance.

2. *Decision makers—private/academic entrepreneurs and public (governmental, subgovernmental) actors*: Two different groups of decision makers are being addressed simultaneously: (1) private entrepreneurs (firms, commercial firms, academic firms) and academic entrepreneurs (universities), interested in optimizing knowledge management and in developing heterogeneously com- posed knowledge-based research networks; and (2) public (governmental, subgovernmental) actors that are interested in optimizing and further developing their policies and policy strategies that target knowledge and innovation. One purpose of public knowledge and innovation policy is to enhance the performance and competitiveness of advanced economies.
3. *Decision makers in general*: Decision makers are systematically being supplied with crucial information, for how to optimize knowledge-referring and knowledge-enhancing decision-making. The nature of this "crucial information" is conceptual as well as empirical (case-study-based). Empirical information highlights practical examples and points toward practical solutions (perhaps remedies), conceptual information offers the advantage of further-driving and further-carrying tools of understanding. Different groups of addressed decision makers could be decision makers in private firms and multinational corporations, responsible for the knowledge portfolio of companies; knowledge and knowledge management consultants; globalization experts, focusing on the internationalization of research and development, science and technology, and innovation; experts in university/business research networks; and political scientists, economists, and business professionals.
4. *Interested global readership*: Finally, the Springer book series addresses a whole global readership, composed of members who are generally interested in knowledge and innovation. The global readership could partially coincide with the communities as described above ("academic communities," "decision makers"), but could also refer to other constituencies and groups.

Elias G. Carayannis
Series Editor

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Chapter 1
Introduction to Multiple Helix Ecosystems for Sustainable Competitiveness

Marta Peris-Ortiz, João J. Ferreira, Luís Farinha, and Nuno O. Fernandes

Abstract This chapter summarizes the evolution of the metaphorical concept of the triple helix, through the quadruple helix and quintuple helix; the second Leydesdorff (J Knowl Econ 3(1):25–35, 2012), a founder of Triple Helix, invites the submission of other model proposals with more than three helices. Based on the literature review on these currents of collaborative interaction for innovation, knowledge and technology transfer, we set out to build a conceptual model that can help explain the improvement of sustainable competitiveness of economies and companies. The model has been designed from the concept of "Multiple Helix Ecosystems for Sustainable Competitiveness", opening doors to its empirical verification.

1.1 Introduction

In general, theories apply numerous times in different areas, from natural areas to different disciplinary domains. As an example, the theory DNA (Deoxyribonucleic Acid) is applied from molecular biology, agriculture, environment, human health,

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animal health, etc. The adaptation of these theories to economic and management sciences can also be observed.

The 'triple helix', or university–industry–government interaction, theoretical current advocated by Leydesdorff and Etzkowitz (1996), has been increasingly recognized as the source of the competitiveness of nations, that drives the transformation of scientific and technological outcomes into economic outcomes, massively associated with the context of innovation management (Etzkowitz and Leydesdorff 1995; Etzkowitz et al. 2005; Etzkowitz 2008; Kim et al. 2012; Leydesdorff 2000).

The pressures of a global financial and economic crisis, further highlight the importance of reflecting on the competitiveness of economies and business (Potts 2010). Through a simplified view, competitiveness can be viewed as the success with which the economies and businesses can achieve a permanent competitive environment not only at the market level but also with regard to the ability to attract financial resources and human capital (Audretsch et al. 2012). The productive competitiveness of business and the stability of relationships between the different actors involved in the processes of innovation, transfer of knowledge and technology, have also been included within the Triple Helix framework (Etzkowitz and Leydesdorff 2000; Etzkowitz 2003a, b; Cooke and Leydesdorff 2006). According to the logics underpinning regional development, the predominance of the Triple Helix relationships and specific local activities (for example, local technology transfers, the development of human capital and networking), in conjunction, determine better overall results (Lawton Smith and Bagchi-Sen 2010).

Contemporary relationships deriving from ongoing interactions between the spheres of university and industry are resulting in a third hybrid current from common interests in basic research, partnership projects between industry and higher education institutions as well as through the joint establishment of research and development programs providing recourse to multiple sources of financing (Etzkowitz 2008).

The Triple Helix approach provides some evidence that universities may perform an enhanced role in innovation within the context of knowledge based societies (Etzkowitz 2003a, b; Etzkowitz and Leydesdorff 2000; Etzkowitz and Dzisah 2008; Leydesdorff and Meyer 2006).

Academia has become entrepreneurial broadly through internal dynamics while also driven by external contacts to private sector firms within the scope of research contracts and transfers of knowledge and technology (Etzkowitz 2003b). Given this progress in understanding the transformations taking place in economic relationships, the priority has become the clarification of the core features of interest and the perspectives they encapsulate (Cooke and Leydesdorff 2006).

According to Etzkowitz (2003a), the triple helix dynamic is based upon the range of agreements and partnership networks occurring between the respective institutional triple helix spheres and is actually better at advancing new sources of innovation in comparison with any isolated initiative designed to generate such results. Correspondingly, attention is drawn to incubators and science parks in conjunction with the networks established between the different triple helix partners driven by a shared desire for research based cooperation and the implementation of new entrepreneurial projects. Aligning the triple helix system to the

regional competitiveness factor and the innovative activities of local companies, based upon knowledge and high technology, confirms the point of departure for a better theoretical understanding (Galindo et al. 2011).

The metaphor of a Triple Helix invites proposals to extend the model to more than three helices (Leydesdorff 2012).

1.2 From Triple to Multiple Helix

The evolution of innovation systems and the current dispute over which path is most appropriate for university–industry relationships effects the different institutional agreements in terms of the overall university–industry–government relationships (Etzkowitz and Leydesdorff 2000).

State– industry–university relationships have been subject to various configurations over the course of history (Fig. 1.1).

In the first configuration (I—State-centric), the reach of the state extends over both industry and the higher education system and guides and structures their mutual relationships. This model was implemented to an extreme extent in the Soviet Union and the former Socialist countries of Eastern Europe and remains in effect in far weaker versions in some European countries such as Norway (Etzkowitz and Leydesdorff 2000).

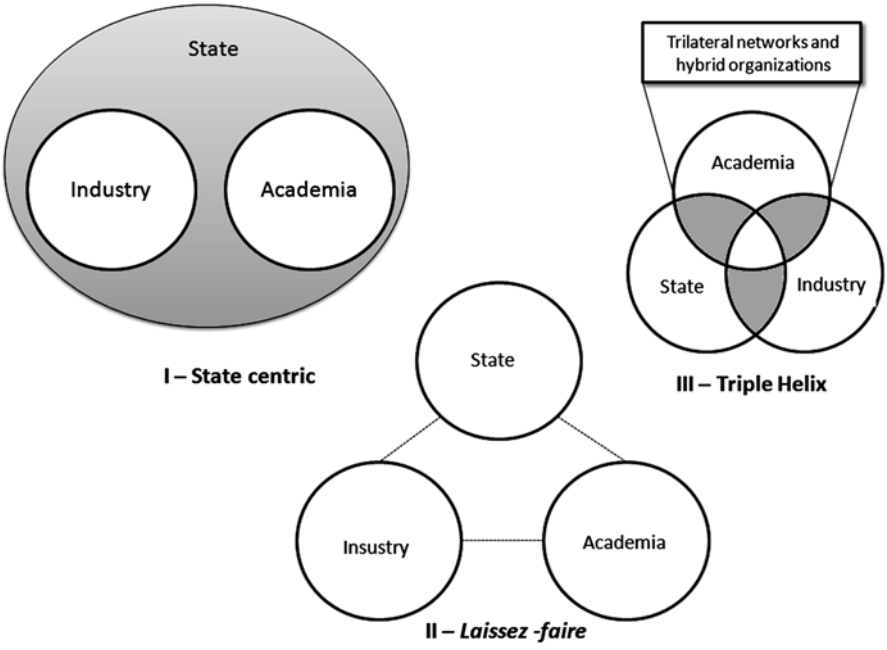

Fig. 1.1 From "state-centric" to the *laissez-faire* and triple helix models. *Source*: Etzkowitz (2003a, b:302)

The second model of political decision making (II—*Laissez faire*) involves the separation of the three institutional spheres: university–industry–government through the intermediation of strong barriers with only modest mutual interactions and highlights the existence of autonomous movement in the direction of a new global model for managing knowledge and technology (Etzkowitz 2003a; Etzkowitz and Leydesdorff 2000).

The evolutionary perspective of model (III—Triple Helix) facilitates the generation of a knowledge based infrastructure overlying the different institutional spheres, where each takes on the role of the other within the framework of an emerging tripartite interface between hybrid organizations (Etzkowitz and Leydesdorff 2000).

Given contemporary societies are no longer coordinated by some central power, a "Rome" or a "Moscow", but which function in terms of interactions through diverse codified communications, the current triple helix model is open to the presentation of proposals extending the model to four or more helixes (and potentially incorporating an alphabet of twenty or more helixes). This would expand its potential coverage to new communication variables which could include power, truth, trust, emotional intelligence or other interfaces relating to intellectual property protection rights (Leydesdorff 2011).

Reinforcing this thesis of expanding the triple helix model, MacGregor et al. (2010) defend how the triple helix innovation process may serve as the core foundational model for evolutionary progression to a quadruple helix that totally integrates the spheres and where the overlapping roles serve to create or discover new knowledge, technologies or products and services from a perspective of meeting a social need. Making references to studies undertaken by different authors, Leydesdorff (2011) highlights the case of Japan in the 1990s in which the addition of an extra, fourth, helix was necessary as an addition to the ongoing relationships between university–industry–government, internationalization also played an important role in the economy just as the emergence of the Internet deepened and strengthened globalization through the provision of a new means of professional communication.

The Quintuple Helix innovation model introduced by Carayannis and Campbell (2010) is a framework for facilitating knowledge, innovation and sustainable competitive advantage. It embeds the Triple and Quadruple Helix models of Etzkowitz and Leydesdorff (2000) and Carayannis and Campbell (2009), respectively, by adding a fifth helix, the "natural environment". The Triple Helix model focuses on the university-industry-government relation, while the Quadruple adds the "media-based and culture-based public" and "civil society" as a fourth helix. Within the framework of the Quintuple Helix model, the natural environment and the economy should be seen as drivers for sustainable competitiveness and prosperity.

1.3 Networks of Innovation and Competitiveness

Innovation is now a decisive challenge for global competitiveness; to achieve successful regions and companies have to know how to deal with the derived issues, leveraging the strengths of their location for the creation and commercialization of new products and services. In advanced economies, producing

standardized products, with recourse to standard methods and processes, is now insufficient to attain competitive advantage. Companies need the skills and capacities to innovate in the global marketplace, designing, inventing, producing and selling a flow of new products, advancing the frontiers of their state of the art technology and evolving faster than their rivals. According to Porter and Stern (2001), this is characterised by capacities, within the terms of free and fair markets, to produce goods and services able to meet the prevailing needs in the marketplace, maintaining and increasing the flow of earnings to their population in the long term (Budd and Hirmisf 2004). Furthermore, two of the leading reasons which strengthen the competitive pressures are the growing international mobility of capital and the openness of markets in conjunction with phenomena derived from globalization. Economies have strengthened their interdependence by increasing levels of both exports and imports, boosting direct foreign investment, removing barriers to trade and the transnational organization negotiating powers over the transport sector (Turok 2004).

Innovation is generally accepted as a critical parameter of human intelligence and cognitive capacities (Galindo et al. 2011). The regional innovation concept is based on an interactive set of private and public interests, formal institutions and other entities that operate in accordance with organizational and institutional agreements and establish relationships leading to the generation and dissemination of knowledge. The concept involves analyzing the existence of actors (institutions, groups, universities, industries, …) and regional competences as well as the ongoing inter-network interactions engaged with innovation related purposes within the scope of the overall objective of providing the local and state authorities with tools for defining policies able to boost real competitiveness (Huahai et al. 2011). Representing the foundation stone of the stone of the triple helix model, intellectual resources are, in principle, continually renewable, subject to strengthening and deepening, and therefore stand out as the single best source for regional development (Etzkowitz and Dzisah 2008). The theory of economic growth has undergone an impressive rebirth in recent times, particularly in terms of the publication of studies on the new economic geography based on endogenous growth theories and serving to heighten global interest in the driving forces and socioeconomic impacts of innovation and entrepreneurship.

A strong current of authors argue that entrepreneurial activities, especially when focused on factors of innovation, provide the key to economic and social development (Audretsch and Belitski 2013; Audretsch et al. 2012; Audretsch and Fritsch 2003; Landström et al. 2012; Landström and Johannisson 2001; Witt 2002, 2004; Ylinenpää 2009). Innovation (from new technological and non-technological knowledge) and the sophistication of the business (which includes the factor of production efficiency, the quality of management operations and organization strategies, the quality of cooperation networks between business and stakeholders, the capacity for agglomeration among firms operating in regional clusters, the quantity and quality of local suppliers, among others), represent the foundations for development in advanced economies (Batterink et al. 2010; Gellynck et al. 2007; Karlsson and Warda 2014; Schwab 2013).

1.4 Sustainable Operations Management

The concepts of competitiveness and sustainability are linked at both, country (regional) and company levels. At the regional level, the European 2020 strategy defines a vision of Europe's social market economy for the twenty-first century and proposes three mutually reinforcing priorities: smart growth (developing an economy based on knowledge and innovation); sustainable growth (promoting a more resource efficient, greener and more competitive economy); and inclusive growth (fostering a high-employment economy delivering social and territorial cohesion).

At the company level, operational decisions determine the employed technologies and the design of their production and distribution systems (Drake and Spinler 2013). These in turn determine how efficiently the production factors are consumed, namely materials and energy, as well as the type and extent of waste and emissions produced during both a product's manufacture and its use. As such, operations management is directly responsible for a large proportion of the decisions and the activities that give rise to environmental problems, and therefore, potentially has a major role to play in contributing to solutions for sustainable competition. If sustainable competition is put into practice, it is critically important that operations management embraces the required strategies, tactics and techniques, and operational policies to support economic (profit), environmental (planet) and social (people) objectives and goals.

Sustainable Operations Management (SOM) is therefore attracting increased interest among researchers and practitioners. The growing importance of SOM is driven mainly by the escalating deterioration of the environment as the raw material resources diminish and the pollution levels increase. SOM can reduce the ecological impact of industrial activity without sacrificing quality, cost, reliability and logistic performance. This book explores ways in which SOM must develop in order to play a full and effective role in progress towards sustainability. Three main issues are addressed: (1) green product development; (2) lean and green operations management; and (3) green supply chains.

1.5 Constructing a Conceptual Model for Sustainable Competitiveness

Contemporary society turns out to be more complex than even molecular biology and exhausts the scope of the double helix model to explain inter-related phenomena. However, the literature on the emergence of the triple helix model unanimously states the need for university–industry–government interactions to become the key to innovation in knowledge based societies (Etzkowitz 2003a).

The socio-economic prosperity of countries and regions depends on their competitive advantages, including their positioning in global markets, their ability to attract investment (including direct foreign investment), their ability to attract and

retain skills, which together dictate their overall ability to generate wealth, job creation and social welfare (Buesa et al. 2010; Cantner et al. 2008; Stajano 2006).

The triple helix development model fundamentally rests on the paradigm change from an industrial society to a knowledge based society. This correspondingly attributes an important role to innovation and development through their roles in transferring knowledge and technology (Etzkowitz 2003a, b; Etzkowitz and Dzisah 2008; Galindo et al. 2011); reflected in the various different institutional agreements in terms of the relationship between spheres and the transformations taking place in terms of the economic relationships in effect (Etzkowitz and Leydesdorff 2000; Cooke and Leydesdorff 2006).

Given the changes in societies that have shaken off domination by a central authority, some authors have felt the case for presenting possible new alternative model scales with four or more helixes based on new variables (Leydesdorff 2011; MacGregor et al. 2010) fostering regional competitiveness and development (Audretsch et al. 2011). Appointing innovation as the decisive challenge to overall levels of competitiveness, Porter and Stern (2001) refer to a model framework portraying necessary innovative capacities and reporting on the specific infrastructures and clusters present in innovative environments.

Appointing innovation as the decisive challenge to overall levels of competitiveness, Porter and Stern (2001) refer to a model framework portraying required innovative capacities and reporting on the specific infrastructures and clusters present in innovative environments.

Backing up this perspective on how regional competitiveness and development determine the productive capacity of companies and regional levels of income and employability (Budd and Hirmisf 2004), other authors highlight the predominance of relationships between university–industry–government (state, regional or local) and specific local activities in determining the best business results and outcomes (Lawton Smith and Bagchi-Sen 2010). A set of political entities, industrial organizations and academic institutions jointly work together within the overall objective of boosting the conditions for innovation and organization able to drive regional development processes (Etzkowitz 2008).

Beyond exogenous developments, brought about by the arrival of technology and direct foreign investment, endogenous resources now require new standards of competitive improvement. The rising levels of local intellectual capital and institutional support (Etzkowitz and Dzisah 2008) enable the development of an interactive group of private and public interests, acting through a network of organizational and institutional agreements and fostering the dissemination of knowledge, technologies and regionally located innovation skills and capacities (Huahai et al. 2011).

Sustainable competitiveness has been widely discussed among academics and practitioners, considering the importance of protecting the environment while sustaining the economic goals of organizations (Wilkinson et al. 2001; Kleindorfer et al. 2005; Piplani et al. 2008). The World Economic Forum defines sustainable competitiveness as "the set of institutions, policies, and factors that make a nation productive over the longer term while ensuring social and environmental sustainability" (Schwab 2014:55). Researchers and practitioners are currently dealing

with the challenges of developing business and innovation models that integrate issues of competitiveness and sustainability (see e.g., Carter and Rogers 2008; Lee 2011; Etzkowitz and Leydesdorff 2000; Carayannis and Campbell 2009, 2010; Carayannis and Rakhmatullin 2014).

In order to facilitate the reader's understanding of the entire literature review, we developed the following model synthesis referred to as the "Multiple Helix Ecosystem for Sustainable Competitiveness" (see Fig. 1.2).

The figure above shows our proposed model "Multiple Helix Ecosystem for Sustainable Competitiveness". In a metaphorical way, the model is based on the interaction between the spheres of Academia, Industry, Policy Decision, hybrid organizations (created from the interaction of these helixes) and more helixes that can claim relevance in the context of economies and firms.

The model thus integrates Academia as the "key of knowledge", as the actor responsible for the knowledge and technology transfer for organizations but also for their participation in the innovation process. The industry is the "production key", the developer component of economy. The government or the political decision (national, regional and local), is the "key to stable interactions", resulting in the production of tax and market regulations, even assuming the role of facilitator in the

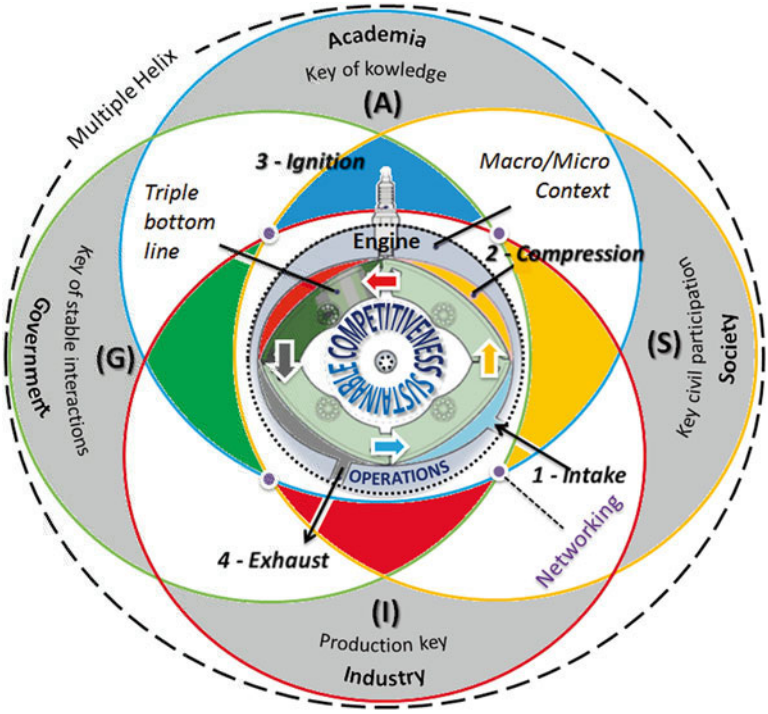

Fig. 1.2 Multiple helix ecosystem for sustainable competitiveness. *Source*: Authors