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

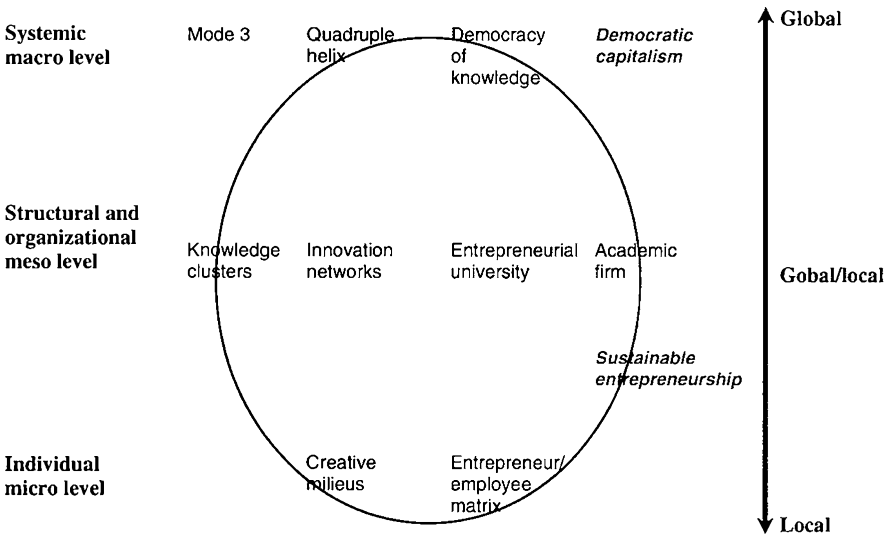
[1] We define *sustainable entrepreneurship* as the creation of viable, profitable, and scalable firms. Such firms engender the formation of self-replicating and mutually enhancing innovation networks and knowledge clusters (innovation ecosystems), leading toward robust competitive- ness (E.G. Carayannis,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

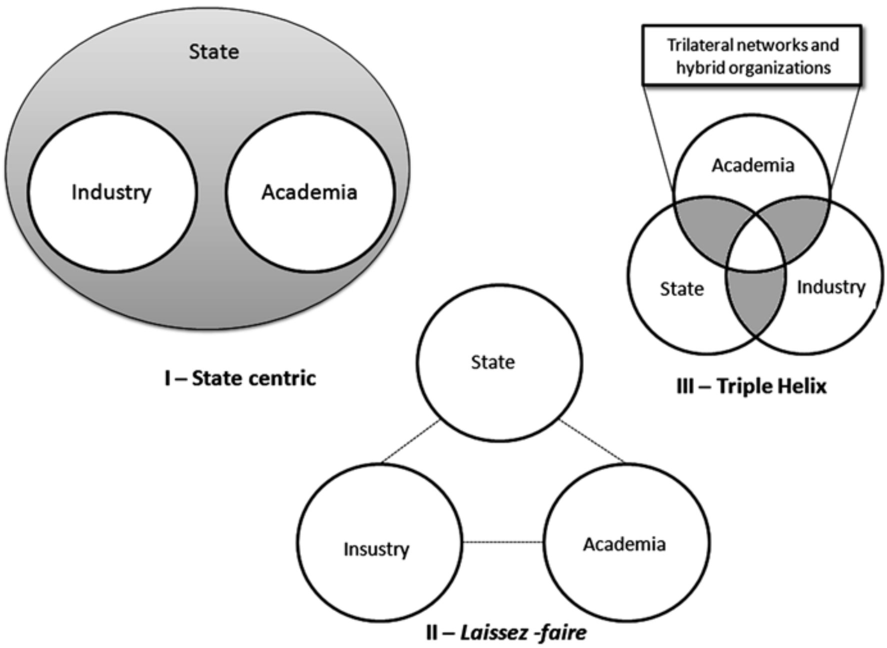

Fig. 1.1 From "state-centric" to the *laissez-faire* and triple helix models. *Source*: Etzkowitz (2003a, b:302)

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

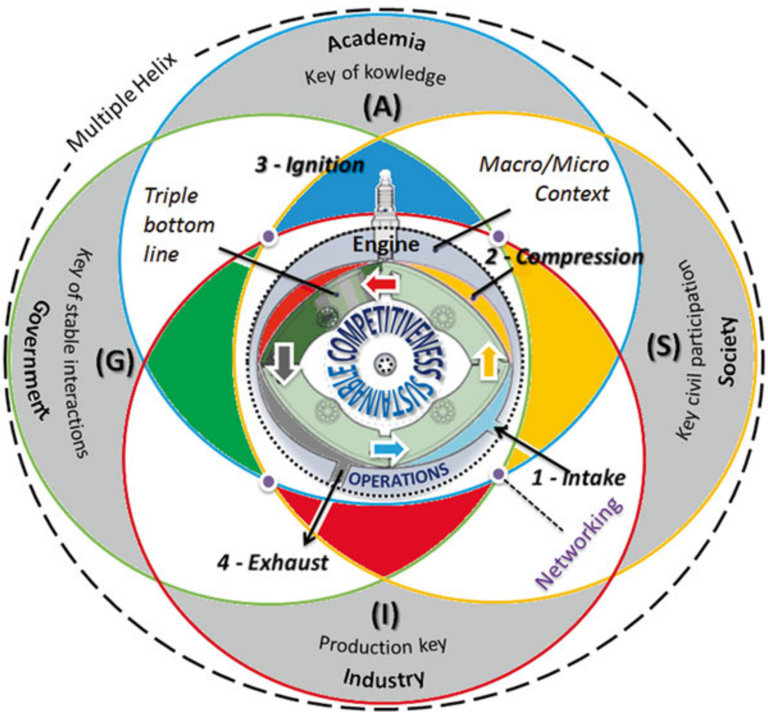

Fig. 1.2 Multiple helix ecosystem for sustainable competitiveness. *Source*: Authors

access to public funds. Civil society also assumed to be the end user of the ecosystem is the "key to participation" in this process.

In our model, the Quintuple Helix, is present in the management of ecosystem operations through the triple bottom line (at the economic, environmental and social level), thus ensuring the presence of drivers for sustainable competitiveness and prosperity.

However, if we focus on the model's centre, we can observe, in a figurative sense, the internal combustion engine, we have called the "Sustainable Competitiveness Engine" (see Fig. 1.3). This internal combustion engine represents the dynamics of sustainable competitive from four cycles of operation: (1) Intake; (2) Compression; (3) Ignition; and (4) Exhaust.

According to Gopalakrishnan et al. (2012), sustainability should also be perceived within a three-dimensional approach: environmental (triple bottom line), economic-financial and social, thereby boosting the competitive advantage of regions.

As can be seen in Figure 1.3, the phase 1, "Intake", starts the engine operating movement for sustainable competitiveness through the entrance of required inputs: productive factors, technology readiness, and innovativeness of economies and companies. In the second phase of operation, there is the "Compression", by adjusting factors of the external environment. The third phase, "Ignition" is the detonation, the action, the "make it happen". Again, the interaction of different institutional spheres (helixes) is a significant demonstration. Finally, we have the "Exhaust", which symbolizes the negative impact of the combustion engine. Here we find the

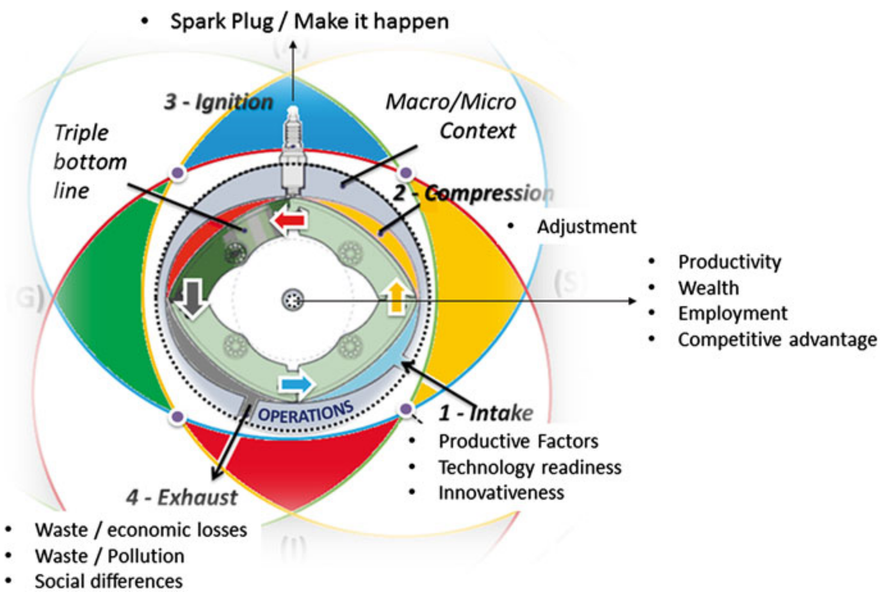

Fig. 1.3 Sustainable competitiveness engine. *Source*: Authors

waste resulting from inefficient operating processes, loss of productivity and the economic, waste, environmental pollution, social, and other outputs resulting in losses of sustainable competitiveness.

1.6 Conclusions

With a strong presence in the development of collaborative R&D+I projects in the triple helix action sphere, the cluster works in the areas of "product, engineering and process", "innovation, prospecting and networking", projects "to sensitize young people to the industry" and other transversal programmes that aim to enhance cluster intelligence and competitiveness.

A leading group of authors argues that research and innovation policies tend to concentrate within AI interactional contexts through the development of new projects and new technologies for the market and thereby making an important contribution to regional competitiveness (Bennett et al. 2012; Bjerregaard 2010; Perkmann et al. 2011, 2013; Petruzzelli 2011; Plewa et al. 2013; Soete and Stephan 2004; Vaz et al. 2014).

Regarding the structure of the book, the purpose of Chap. 2 is to analyze from a multiple helix approach, the relationships between industry, government, business, society and the natural environment in the Great Barrier Reef region of Australia. The aim of Chap. 3 is to project the agency theory about triple helix, proposing a new model of governance framework. Chapter 4 challenges the TH literature's traditional emphasis on the university as the main driver of innovation, the case of Abengoa, a multinational leader in renewable energy industry, specializing in innovative, sustainable biotechnology and biochemistry solutions. Chapter 5 analyzes the role of triple-helix collaboration in two regions—Øresund, Danish-Swedish cross-border region, and the Moscow region. The focus is on the role of the university in stimulating clean technology (cleantech) entrepreneurship. Chapter 6 of the book identifies key factors that influence green product development and discuss their implications. A comprehensive literature review analyzing the state-of-the-art concerned with green product development, along with results of surveys and cases, sustains the qualitative discussion on the key factors that influence the development of products. Authors also develop a framework derived from a Multiple Helix approach on green product development that identifies the key factors associated to the main actors, as well as their interrelationships. Chapter 7 of the book provides a state of the art and literature review on the use of Sustainability, Lean, Green and eco-efficiency concepts, as well as meaningful combinations of those, in the field of Operations Management. Chapter 8 of the book aims to propose a five step model to supply chain sustainability performance assessment. The model is based on the Balance Scorecard framework to define the company sustainability strategy and uses Global Reporting Initiative (GRI) and ISO 14031 indicators to measure the sustainability performance of it upstream supply chain. Chapter 9 presents a triple helix collaborative project carried out through the collaboration of members of three Universities in order to analyze the impact of shortening changeover time on production flexibility in an Industrial Company. The aim of Chap. 10 is to analyze nanotechnology from a sectoral innovation perspective and to advance the necessary conditions to implement it. Finally, the purpose of Chap. 11 is to analyze the impact of venture capital on the growth of university spin-offs.

In summary, the book intends to discuss the main issues, challenges, opportunities, and trends involving academia, industry government and society interactions, able transform and enhance the business models and the way companies produce products and deliver services, from the sustainable competitiveness point of view, and to disseminate current developments and practical solutions and applications.

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Chapter 2
Multiple Helix Approaches to Sustainable Entrepreneurship and Innovation: A Case Study of the Great Barrier Reef (Australia)

Vanessa Ratten

Abstract The purpose of this chapter is to analyze from a multiple helix approach, the relationships between industry, government, business, society and the natural environment in the Great Barrier Reef region of Australia. The main findings suggest that innovation systems are important in sustaining World Heritage Areas such as the Great Barrier Reef. As the world's largest marine park the results highlight the influence of university-industry-business on the regional development and innovation of the area. The chapter has implications for practice in terms of highlighting the importance of sustainable entrepreneurship approaches and theoretical implications for the design of research linking multiple helix approaches to the natural environment. Suggestions for future research linking regional innovation policies to the natural environment and sustainability are stated.

2.1 Introduction

There is a growing awareness of nature-based enterprises and how conservation solutions depend on social, political and economic collaboration between individuals, institutions and society (Moon et al. 2014). This has increased recently with the shift in the innovation policy and practice literature from confining sustainability to a single business aspect to focusing more on the interaction amongst the government, education, business, environment and society. This shift involves a rethinking of how entrepreneurship helps contextualize sustainability initiatives and the important innovation dynamics involved. Part of this change involves the collaboration of multiple stakeholders with both temporal and spatial elements, which are in combination to the natural environment (Balmford and Cowling 2006). In nature

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industries, society places value on the interaction between academia, research and industry with sustainability issues to ensure appropriate conservation planning.

This chapter will focus on a multiple helix approach to examining sustainability entrepreneurship and collaboration in Australia's Great Barrier Reef, which is the world's largest marine park and amongst the most popular tourism destinations (Biggs 2011). The Great Barrier Reef is located in the North-east part of Australia in Queensland and is more than 1200 km, which means it comprises a geographic area of 350,000 km^2 (Biggs 2011). Overall, there are more than 900 islands and 2900 individual reefs in the Great Barrier Reef (Johnson and Marshall 2007). Most of the reefs are within 20 km from the shoreline making the area easily accessible to tourists. The nearest cities from the reef are Cairns and the Whitsunday region.

This chapter will utilize a case study approach of the Great Barrier Reef to see how the quintuple helix is applied through green innovation systemic analysis. Green innovation is part of system innovation as it focuses on environmental and sustainability change. This is important as innovation based systems try to mitigate the disadvantages to the environment by creating new growth engines (Deak and Peredy 2015). The premise of green innovation is on connecting enterprises, government and individuals to pursue environmentally friendly initiatives. This means using a holistic strategy to connect environmental concerns regarding energy consumption and urban development.

This chapter is structured in five main sections. First, the importance of having a multiple helix approach to innovation systems is stated. Second, the role of sustainable entrepreneurship for the Great Barrier Reef region of Australia is discussed. This involves conceptualizing the role of the university in the regional innovation systems and sustainability initiatives. Third, the case study is discussed in terms of linking university, industry, government and society to sustainable entrepreneurship. The fourth section discusses the findings of the study and the final section contains reflections about the significance of the study for understanding sustainability entrepreneurship from a multiple helix perspective.

2.2 Literature Review: Multiple Helix Approaches

The multiple helix approach to innovation suggests that generative relationships involve a number of different stakeholders. These reciprocal relations with government, industry and business must have a societal need if they are to advance current innovation thinking. The promotion of innovation in a socio-economic environment progresses the need to encapsulate government policy with sustainable management practices. The multiple helix model incorporates knowledge capitalization by focusing on the mutual influence and transformation of networks existing in a regional context. The main stages of this knowledge-based economic development involve creating a space for information dissemination, consensus then innovation (Etzkowitz et al. 2001).

The first part of multiple helix studies involving innovation involves the concept of the triple helix. The triple helix model incorporates university-industry-government relationships, which involve components such as technology transfer, collaborative leadership and networking to produce innovation (Ranga and Etzkowitz 2013). Knowledge has become increasingly important to society as new businesses in the internet economy emerge. The application, production and transfer of knowledge involve elements from university, industry and government to create an innovation system. The triple helix model of innovation systems comes from the shift in studies focusing on industry-government to incorporate the role of universities in the knowledge economy (Ranga and Etzkowitz 2013). Businesses that can innovate and adapt are more likely to be resilient to change and the triple helix model is considered a core model for innovation but has been widened in scope to incorporate societal linkages (Villareal and Calvo 2015).

Originally, the triple helix model came from university-industry research, which found that the government is an important part of the relationship and focuses on three types of organisation: universities to spread knowledge, government research and innovative organizations (Deak and Peredy 2015). The focus of the triple helix is on the collaboration between industry, academic and administrative functions that strengthens knowledge integration (Leydesdorff 2012). The triple helix model of knowledge suggests that a national innovation system results when three helixes combine (university, industry, government relations) (Carayannis and Campbell 2009). These helices overlap to create hybrid organizations that incorporate elements of each helix (Etzkowitz and Leydesdorff 2000).

The quadruple helix includes the original triple helix but adds civil society into the conceptualization (Carayannis and Campbell 2009). Society is important in creating knowledge from the knowledge-based economy and is an addition to the helix models for explaining an innovation ecosystem particularly as it relates to sustainability. Media and cultural aspects of life incorporated into the definition of civil society (Villareal and Calvo 2015). Culture is an important addition to the studying of multiple helix ecosystems approaches as it acknowledges the importance of history and tradition on society. The quadruple helix originated from the triple helix but incorporates media and culture, which is important to societal wellbeing. The additional fourth helix includes the creative industries, which highlight the culture, values and lifestyle of a society (Carayannis and Campbell 2009). This creative class focuses on the role of art and culture, which was missing from the original triple helix model. The reason for adding the additional helix is due to the role the media has in national innovation systems. Increasingly the media in terms of cultural values espoused by a society influences technology and change, which is linked to innovation. This has led to the term ‘innovation culture’ or ‘entrepreneurial society’ being used to popularize the type of lifestyle people engage in. In knowledge-based economies, the linkage between entrepreneurship, innovation and culture is becoming more important. This is evident when knowledge producers are brought together to establish research networks (Carayannis and Campbell 2009). This complementary knowledge coupling between university research and business enables creative pursuits to be encouraged. The media is utilised to capture the political and social reality existing in the knowledge economy.

The quintuple helix brings another addition to the quadruple helix model by adding the natural environment (Carayannis and Campbell 2009). The natural environment incorporates that view that sustainability is increasingly important in innovation management practices. The economy is linked to the natural environment and this plays a role in knowledge production (Villareal and Calvo 2015). The role of the natural environment in innovation in the quintuple helix model highlights the changing role of innovation systems in society. The natural environment has become more important to innovations studies due to sustainability issues being at the forefront of business, government and education decisions. The next section will discuss the role of sustainable entrepreneurship in the multiple helix system and regional innovation.

2.2.1 Sustainable Entrepreneurship

More attention is being placed on sustainable development, which is meeting the needs of the present without hurting future generations (Pacheco et al. 2010). The ability to integrate future expectations from society is at the heart of sustainable development as it integrates the innovative aspect of entrepreneurship with sustainability. Sustainable entrepreneurship has also been referred to as green entrepreneurship, environmental entrepreneurship and eco-preneuring (Pacheco et al. 2010). This is due to opportunities being created by entrepreneurs through a process of effectuation (Pacheco et al. 2010). This involves substituting economic potential by evaluating needs with resource requirements. Part of this process incorporates the idea that rather than discovering ideas, entrepreneurs perceive opportunities based on instinct (Gartner 1985). This perception incorporates recursive interaction with economic structures to link need, resource requirements and opportunity recognition.

Sustainable entrepreneurial action embraces the creation of opportunities as a by-product of resource allocation and recognition. The discovery view of entrepreneurial opportunities views economic systems as having gaps or unmet needs that can be exploited by entrepreneurs (Pacheco et al. 2010). Sustainable entrepreneurs discover these entrepreneurial opportunities when there is a incentive for action based on product potential. Therefore, sustainable entrepreneurial action involves examining the external environment to see where opportunities are available.

Sustainable entrepreneurship uses resources in an environmentally friendly way to create profit opportunities. By doing so, sustainable entrepreneurs protect resources from unfavorable behavior and maintain the environment for future usage. They do this by having codes of behavior that integrate business activities, property rights and government policy. Sustainable entrepreneurs integrate the rights of business with that of the environment to encourage collaborate behavior in a natural resource setting. They do this by acting in the interest of both business and society so the resulting behavior is collectively beneficial (Pacheco et al. 2010). Increasingly there is entrepreneurial encouragement of sustainable business development from industry, education and government providers.

Sustainable entrepreneurship opportunities involve linking economic reward systems with exploiting social value needs (Pacheco et al. 2010). The economic incentives for sustainable entrepreneurship opportunities make the exploration of market resources available that link social requirements of society. Some opportunities come from consumer preference changes that highlight the growing acceptance of sustainability in society. Other changes result from alternation in resource policies and technological developments that are exploited by sustainable entrepreneurs. Another type of sustainable opportunity involves altering the market system by creating new markets that have a social element. There is potential for sustainable business models to create value by incorporating social practices into economic activities. The next section will further discuss how sustainable entrepreneurship is integrated into regional innovation platforms that link academia, industry and government with the natural environment.

2.2.2 Regional Innovation

Innovation is important for regional competitiveness and economic dynamics as it is a systemic and interactive process that focuses on the use and generation of knowledge (Deak and Peredy 2015). National innovation systems incorporate education and training systems, intellectual property protection, university-industry networks, venture capital and science parks (Deak and Peredy 2015). These national innovation systems provide the context for positive change to be allocated and supported. Some national innovation systems facilitate this through research and development incorporating academic knowledge.

Innovation systems involve examining the relationships that interact with the use of new and economically useful knowledge within a specific region (Lundvall 1992). The elements of innovation systems highlight the way knowledge is produced and diffused. System innovation involves an interconnected set of innovations, whereby each part of the system influences the other (Deak and Peredy 2015). The components of systemic innovation work together so they form a kind of architecture. Within systemic innovation the main types of innovation are incremental, modular, architectural and radical (Henderson and Clark 1990). Incremental innovation involves small changes that have the main components reinforced. Modular innovation has the components overturned in the architectural system without affecting the overall system architecture. Radical innovation involves major changes with the components and architecture of the system altered. Architectural innovation changes the linkages between the systems to reconfigure the overall structure (Deak and Peredy 2015). System innovation requires multiple changes and collaborations within the various stakeholders (Maula et al. 2006). This is due to system innovations having adjustments to other parts of the business relationships. The fourth sector or civil sector is connected to the business, science and technical areas of the helixes.

The ability of a region to create and nurture new knowledge is important for economic development (Audretsch and Keilbach 2004). The competitiveness of a region is evaluated by its ability to maintain and increase social welfare and economic ability of its community (Gonzalez-Perreira et al. 2012). Regional innovation capability is the ability of a region to create new knowledge and this is important in accessing opportunities for innovation (Gonzalez-Perreira et al. 2012). More regions are focusing their innovative capabilities on entrepreneurial activity that attracts economic growth (Sternberg and Wennekers 2005). This is due to entrepreneurship positively affecting productively as market entrants give firms increased competition (Audretsch and Keilbach 2004). Regional entrepreneurial capability can take a variety of forms including the creation of new jobs and adding sophisticated services into the marketplace (Gonzalez-Perreira et al. 2012). In order to improve regional productivity more emphasis on the creation of innovative products, services and technologies enabled by new ventures is required (Gonzalez-Perreira et al. 2012). Improved regional productivity will result from the combination of better innovation capacity with economic development processes.

Innovative entrepreneurs in a region take advantage of existing knowledge to create opportunities that use underutilized resources (Hessels et al. 2008). Some of this entrepreneurial activity involves creative construction when existing knowledge is utilized for another purpose (Ratten 2015). This can involve innovation not necessarily displacing existing firms in the market by recognizing business opportunities unseen by others (Ratten 2016). This wealth of a region increases when entrepreneurial activity is effective and new knowledge is generated (Audretsch 2009). Entrepreneurs have an important role in commercializing new knowledge that leads to regional innovation (Audretsch and Keilbach 2004).

The ability of a region to generate new knowledge is a distinctive capability that affects innovation (Wong et al. 2005). These are regional-specific elements including labour, land and location that drive the distinctive capabilities of a region. Both innovation and entrepreneurship simultaneously matter in creating knowledge that leads to economic growth. Regional capabilities involve a regions capacity for innovation and to create firms based on the social capital existing within a geographic area (Best 1999). This capacity is based on the tangible and intangible sources of knowledge that supports productivity growth and regions know-how. Audretsch (2009) proposed that an entrepreneurial society will come from innovating and entrepreneurial regions having a high level of productivity. Regional efforts to innovate are a source of growth for entrepreneurial societies (Acs et al. 2009). Innovation comes from companies creating new ventures that are fundamental to the economic sustainability of a region. Sustainable innovation is a separate category of regional innovation due to its relationships with the natural environment and this will be discussed in the next section.

2.2.3 Sustainable Innovation

Deak and Peredy (2015) state that policy makers are interested in the role of innovation because of climate change, transport efficiency and environmental sustainability. These issues are system innovation concerns due to the large socio-economic impact they have on the business environment. In addition, the new information and communication technologies linked to renewable resources has meant more attention being placed on the role of the environment within system innovation. In system innovations, the governance of the relationships are in the interaction between institutions, regulations, consumers and governments. The diffusion of innovation in a system benefits development and spurs business investment.

Sustainability is at the core of many environmental parks that need innovative partnerships to survive (Boutin 2010). Nature reserves are a good example of multiple helixes due to the economic and human values associated with conservation and sustainability (Hall 2010). This is due to nature reserves relying on the interaction between individuals, organizations, society and the government to protect and preserve the geographic area (Biggs et al. 2012). The continued conservation of nature-based areas requires a collaborative approach between government and society in order to enable it to continue (Orams 1995).

Nature-based enterprises encourage conservation with societal benefits such as tourism and education (Marshall et al. 2010). There are a number of ways nature-based enterprises take a multiple helix approach to innovation. Firstly, tourism enterprises contribute to regional development by attracting business and educators to the area for the biodiversity and conservation initiatives (Biggs et al. 2012). National parks and wildlife require constant monitoring and this involves collaboration between researchers and industry. Secondly, tourism enterprises generate awareness about a geographic area by advertising the reasons for society to visit and support the region. This includes generating environmental awareness and nature viewing practices that incorporate sustainability initiatives (Curtin and Wilkes 2005). Direct sustainability initiatives can include "responsible wildlife viewing practices, minimizing energy and water use, and offsetting carbon emissions" (Biggs et al. 2012:1). Thirdly, the sustainability practices of nature-based tourism can lead to more enterprises using resources from the region for business reasons. This can include taking food or fauna from a region then using it in skin care or food products. This enables tourists from the region to partner with business to improve sustainability practices (Powell et al. 2008). The next section will focus on a case study of sustainable entrepreneurship, which highlights the multiple helix ecosystems in the nature-based region.

2.3 Great Barrier Reef: Case Study

The Great Barrier Reef Marine Park was created in 1975 to manage and preserve the reef ecosystem and environment (Biggs et al. 2012). The geographic region of the Great Barrier Reef is made up of over 3000 individual reefs and is the largest group of reefs in the world. There are 600 islands and 300 coral cays within the Great Barrier Reef and the size of the area is bigger than the United Kingdom and half the size of Texas. It is one of the seven natural wonders of the world and includes one of the most diverse collections of marine life. The plants and animals in the Great Barrier Reef include more than 600 types of coral, 100 species of jellyfish and 1625 types of fish. The diversity of marine life on the Great Barrier Reef is reflected in its ecological community making it amongst the most complex ecosystems. Coral reefs comprise approximately 7 % of the Marine Park despite being one of the main attractions to the areas. The other parts of the Marine Park include seagrass, mangroves and sand gardens. There are 14 coastal ecosystems that are with the Great Barrier Reef and these include islands, open water, wetlands, forests, shrublands and estuaries. The Great Barrier Reef lost half of its coral between 1985 and 2012 due to crown-of-thorns starfish, bleaching and pollution.

In 1981, the Great Barrier Reef was the first coral reef ecosystem to receive World Heritage status and received this status due to the recognition of it as a sustainable resource for future generations to enjoy. The region is managed by the Great Barrier Reef Marine Park Authority. Reef tourism and education pays an environmental management charge to sustain the preservation of the area. The Great Barrier Reef is characterized by the relationships between business, industry, education and society in order to enable sustainable entrepreneurship to develop. An example of this relationship is the research on coral-feeding crown-of-thorns starfish, which has lead to the erosion of coral reefs (Biggs et al. 2012). The crown-of-thorns starfish increased in number due to the increase in pollution within the reef ecosystem (Brodie et al. 2005). In order to preserve the reef, the tourism industry partnered with James Cook University to monitor and remove the starfish (Biggs et al. 2012).

The Great Barrier Reef Marine Park Authority has promoted sustainable entrepreneurship by providing an incentive for entrepreneurs to educate themselves by obtaining the Advanced Ecotourism certification (Biggs et al. 2012). Organizations with this certification can obtain an extended tourism permit of 15 years for the Great Barrier Reef that encourages sustainability-based initiatives. Another example of a triple helix system in the Great Barrier Reef is the Minke Whale Project, which comprises James Cook University researchers and government authorities interested in this rare animal. Minke whales migrate to the Great Barrier Reef each winter and they are the only known aggregation of these types of whales in the world. There is little information about the Minke whales due to their scarcity. Minke whales are the most highly patterned type of baleen whales and have a distinctive pattern on each whale enabling them to be individually identifiable. Part of the collaboration between government, education and industry around the Minke whales is due to their attraction for tourists but also because of their unique behavior. Scientists have little knowledge about where they migrate to for the 9–10 months they are not in the Great Barrier Reef area. Industry has partnered with scientists to track Minke whales to see where they relocate to after visiting the Great Barrier Reef. Researchers from James Cook University together with Alaska Sealife Centre use satellite tagging technology to track the Minke whales. Other organisations researching the Minke whales migration include the Australian Marine Mammal Centre, the International Fund for Animal Welfare and donations from the tourism industry. As part of the collaboration between researchers, government and business it has been found that Minke whales travel to the cold Southern Ocean near Antarctica for the time they are not in the Great Barrier Reef.

Biggs et al (2012) suggests that a community of entrepreneurs motivated by sustainability concerns may be helpful for reef conservation efforts. Reef tourism in the Great Barrier Reef involves pollution and there may be better ways to use sustainable energy sources to transport people to the area. Great Barrier Reef Marine Park Authority has devised a Climate Change Action Strategy to reduce the carbon emissions by engaging with industry and the government to use alternative energy sources. This is in conjunction with Australia's Clean Energy Act or the carbon tax that was introduced then repealed because of business concerns with regards to cost implications.

In the Great Barrier Reef conservation agencies including the government and private organizations can contribute to sustainable entrepreneurship in a number of ways (Biggs et al. 2012). They can disseminate information about improved sustainability policies such as recycling and reducing carbon emissions (Zeppel 2011). In addition, they can highlight the conservation efforts can be lobbied for revegetation and protection of the coral reefs. These sustainable entrepreneurship programs are good examples of the quintuple helix approach to regional innovation.

2.4 Conclusions

An integration of sustainable entrepreneurship and innovation systems can advance our understanding of the relationships between socio-ecological systems such as the Great Barrier Reef. Future research should further study how entrepreneurship is sustainable using the government-education-business nexus as discussed in this chapter. An example of a research question that can be addressed is how are multiple helix systems integrating to promote sustainable entrepreneurship in the Great Barrier Reef and how does this compare to other World Heritage sites?

An understanding of the entrepreneurial activity and the helix relationships will shed light on the role of sustainable entrepreneurship in enhancing the performance of regional innovation ecosystems. More research is needed on the role of entrepreneurial universities in the Great Barrier Reef to aid enterprises and policy makers to navigate future environmental changes. This study has represented a starting point for further research taking a multiple helix approach to regional innovation systems about sustainability and reef tourism. Future studies could compare the Great Barrier Reef to other marine parks to see if the government-business-university-society relationship remain the same or are different. Finally, this chapter provides a basis for multiple helix studies to consider the sustainable and entrepreneurship policies to enhance the competitiveness of the region.

Future policy development needs to recognize the synergies between the multiple helix approaches to sustainable entrepreneurship. The recognition of regional innovation and these interdependencies will foster better sustainable entrepreneurship practices for environment regions such as the Great Barrier Reef. More effective policy can result from a integration of sustainability practices with environmental and regional innovation requirements.

This chapter has some implications for public authorities in designing regional innovation development policies. Steps should be taken by public policy planners to nurture an innovative regional ecosystem that encourages entrepreneurship. Policy makers should look at creating innovative regional ecosystems that exploit entrepreneurial opportunities but take into consideration sustainability. This will enable a region to better position them as a sustainable entrepreneurship location that encourages innovation but with a sustainability perspective.

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Chapter 3
Governance for Partnership Sustainability: An Approach from the Agency Theory

Adonai José Lacruz

Abstract The aim of this chapter is to project the agency theory about triple helix; being more specific, corporate governance mechanism about the entity's organizational structure that emerge as intermediaries partnerships within the triple helix (structured as a spin-off, business incubator, business accelerator, science park, among others), having as a base the agency theory. In this context it is proposed a governance framework starting with two drivers that make part of is known as governance throughput: the macro-structure of power and the organization's management macro-processes. In this framework has built an array of classification of governance environment, based on information about the implementation of normative governance mechanisms and supervision generating quadrants with favorable and unfavorable levels of each dimension of governance drives. The proposed framework does not predict optimal decisions about key issues in governance (accountability, disclosure, compliance and fairness), but lists mechanisms to secure theoretical foundation that can mitigate the agency problems, hoping thereby to contribute to better understand the governance environment in partnerships within the triple helix.

3.1 Introduction

The triple helix model holds that an economy based on knowledge, innovation emerges from the interactions between industry, university and government, from the relationships that overlap (intersections) in an environment of bilateral, trilateral and hybrid organizations networks, so that the triple helix is a platform for creating new institutions and new organizational forms such as technology parks, business incubators, innovation centers etc. that arise from the cooperation industry-university-government–the triple helix interface zones (Etzkowitz and Leydesdorff 1995, 2000).

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Studies on triple helix have been done on several nuances and contexts. However, little has been explored the theme in triple helix governance from the perspective of interface organizations that have emerged from the intersections of the partnership industry-university-government.

In this regard it is proposed in this chapter a governance framework for partnerships within the triple helix (Etzkowitz and Leydesdorff 1995)—and its consequences quadruple helix (Carayannis and Campbell 2009), quintuple helix (Carayannis and Campbell 2010) and N-tuple helix (Leydesdorff 2012)—specifically from the perspective of interface organizations that emerge from this relationship structured as technological park, business incubators etc., from the theoretical framework of agency theory—which is one of the most widely used theoretical frameworks in the research on governance. That is, the focus of this chapter is the application of intra-organizational governance agency theory approach to interface organizations, having them as governance inducing in order to create conditions for the sustainability of the partnership given the complexity on inter-organizational governance resulting from heterogeneity of partnership actors (industry-university-government).

In order that the framework is not overly simplistic or overloaded with many variables and conditions, addressed to this dilemma by identifying a relatively small number of dimensions in which the components are postulated to work in an integrated fashion to produce results by designing the framework in two governance drives which make up what is called governance throughput: the macro-structure of power and the organization's management macro-processes. It also built an array of governance environment classification, based on the information about the implementation of governance mechanisms in the normative and supervisory dimensions, creating four quadrants with favorable and unfavorable levels of each dimension of governance drives.

Therefore this chapter is structured as follows: the next section (3.2) recovers the key concepts of triple helix theme by targeting to partnerships in which emerge interface organizations, taken organizationally as the partnership governance inducing element; 3.3 section analyzes the midpoints of agency theory, based mainly in Jensen and Meckling approach (1976); 3.4 section deals with governance, from the perspective of agency theory, and based on this theoretical framework, describes the proposed framework of governance for organizations that emerge from partnerships in the context of the triple helix; and the section 3.5 concludes.

3.2 Triple Helix

The triple helix model holds that an economy based on knowledge, innovation emerges from the interactions between industry, universities and government, from a dynamic relationship, being the industry the production locus, the university the source of knowledge and technology and the government contractual relations provider to ensure stability in the interactions (Etzkowitz and Leydesdorff 1995, 2000). Industry-university-government relations have been the subject of several modeling (Image 3.1):

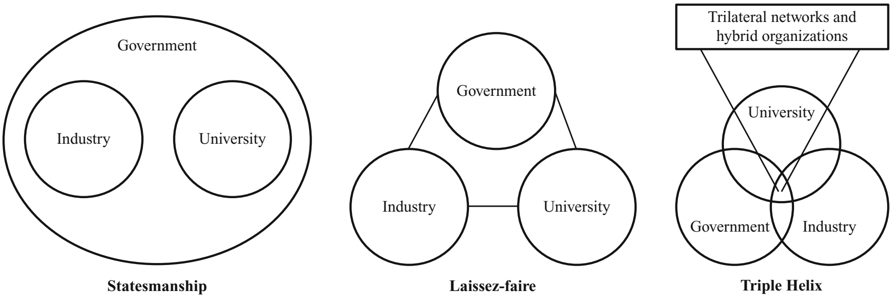

Image 3.1 State models, *Laissez-faire* and Triple helix. *Source*: Adapted from Etzkowitz and Leydesdorff (2000, p.4)

In the first image (state) the cooperation as schemed having the government en-globing the university and the industry, guiding the relations that shall be established; that is, it is up to the government to provide the resources for new initiatives and take the leadership position in the activities. Therefore it is a static model of relation where the government gets involved and guides the relations between the industry and the university.

In the second image (*laissez-faire*)—Sabato's Triangle—there is a clear distinction among the three actors, interacting in an incipient way with strong delimitation of each other; even though having the government in the upper vertex of the triangle, it maintains the role of encouraging the relation, thus making it possible to act as a development stimulant. In the model however, there is a clear independence among the three players.

In the third image (triple helix) it is considered that the relations among industry, university and government overlap. Then this interaction (intersections) establishes the conditions for development of a truly productive relationship to develop an innovation-friendly environment. The role of government becomes to articulate and stimulate partnerships and not to control the relations. Instead of inter-relations among players emerge an environment of bilateral networks, trilateral and hybrid organizations.

The triple helix is therefore a platform for the creation of new institutions and new organizational forms as spin-off, science park, business incubators, business accelerators, innovation centers etc. that emerge from the cooperation industry-university-government (the triple helix interface zones). These "new" institutions are then considered organizationally as governance inducing element of partnerships and often as a condition for the sustainability of an atmosphere on the governance, given the heterogeneity of the partnership agents (industry-university-government).

Studies on triple helix have been done on several nuances and contexts on entrepreneurial dynamics (Kim et al., 2008), on the entrepreneurial university (Meyer et al., 2003), on the role of government as partnership articulator (Todeva 2013), regarding the company's innovation capacity (Luengo and Obeso 2013) among others. However, little has the theme in triple helix been explored from the perspective of governance interface organizations. That is, on the intra-organizational governance of these interface organizations, having them as the partnership governance inducers ahead of an ambiance on the inter-organizational governance resulted from the heterogeneity of the actors of the partnership (industry-university-government).

In this chapter the theoretical framework that supports the proposed governance framework is based on agency theory.

3.3 Agency Theory

The governance framework for partnerships within the triple helix proposed in this chapter has been designed based on the agency theory from a classical approach of Jensen and Meckling (1976). The governance issue had as starting point with the work of Berle and Means (1932), followed by studies on the structure of ownership and the theory of the firm, Coase (1937), Alchian (1965 and 1968), Alchian and Demsetz (1972) and Preston (1975) and on agency costs Wilson (1968), Ross (1973) and Heckerman (1975).

The article by Jensen and Meckling (1976) is considering seminal on studies concerning corporate governance, despite the relevance of previous work and from it, several empirical studies have been developed as well as new theoretical modeling's. It is possible to highlight three main contributions of the work of Jensen and Meckling (1976), in the *stricto sensu*: (1) a new definition of firm as a legal fiction that serves as a nexus for a set of contractual relationships among individuals, (2) a new concept in agency cost, linking it to a division in the ownership and the control in companies and (3) a new theory on firms ownership structure, based on inevitable conflicts of individual interests. On a *lato sensu* perspective, it has contributed to corporate governance definition as a set of internal and external mechanisms, incentives and control, aimed at minimizing the costs coming from agency problems.

From this perspective the firm is defined as a legal fiction serving as a focus for a complex process in which the conflicting goals of individuals are brought into balance within a framework of contractual relations. The firm, therefore, acts as mean to integrate the conflicting goals of several participants from a legal contractual framework in an efficient way. That is, the firm's behavior is similar to the market being the result of a complex equilibrium process (Jensen and Meckling 1976; Alchian and Demsetz 1972).

One of the fundamental assumptions of the agency theory is that there is a conflicting relationship among the goals of parties that make up a set of contracts. The agency theory, in summary, refers to the relationship between the agency, in which one person (principal) hires another person (agent) to perform something that involves decision-making and delegating authority on the main to the agent. This leads to the agency relationship, defined as:

> "[…] a contract under which one or more persons (the principal(s)) engage another person (the agent) to perform some service on their behalf which involves delegating some decision making authority to the agent. If both parties to the relationship are utility maximizer, there is good reason to believe that the agent will not always act in the best interests of the principal". (Jensen and Meckling 1976, p.308)

Taking in consideration that there are differences of interest between the principal and the agent because each one have different utility functions. The foundation of agency theory is on the assumption that one can not maximize a utility function other than your own, as the behavior is based on a set of preferences and one's own goals. When the agent manages resources belonging to the principal having as a reference to maximize your own utility function and not the principal's, such situation is called agency problem (Jensen and Meckling 1976). That is, from the incongruity between the agent's behavior desired by the principal and the agent's actual behavior.

Eisenhardt (1989) adds that the agency theory addresses in addition to the problems concerning the divergence of interests of the principal and the agent, the inherent differences of attitude towards risk; that is, that the agent has preference as to different levels of risk instead of what it would have as the principal.

Jensen and Meckling (1976) say that besides the utilitarian and rational human nature, what makes the agent maximize your utility function, the absence of a contract perfect, able to ensure that the agent aims to serve the interests of the principal and also leads to misalignment between the interests of principal and agent.

Fama and Jensen (1983) clarify that the contracts also give the agents the steps of the decision process. For both authors divide the decision so that unfold in stages, namely: initiation, ratification, implementation and monitoring. Also explain that the initiation and implementation should be combined in the decision management function; and the ratification and monitoring, in the decision control function as these sets are usually performed by the same people. According to the authors an efficient control system means separating the initiation and implementation phases (decision management) and the ratification and monitoring (decision control), as in that way the process is intended to reduce or control agency problems.

Fama and Jensen (1983) complement suggesting the delegation of decision-making functions. The authors discuss the complex nature of the organizations to which the specific knowledge necessary for making different decisions is dispersed among several agents. Therefore, the delegation of decision-making functions to agents with relevant expertise bring potential benefits of better quality decisions. However, the distribution of decisions to agents generates agency problems, given the rational nature of human behavior and the lack of perfect contract presumed by the agency theory. It is suggested as mechanisms to reduce these problems, sharing the management and control functions among different agents.

Jensen and Meckling (1995) provided a more detailed explanation of the need for decentralization of decision-making, based on specific and general knowledge. When knowledge is important in the decision-making process there are advantages in combining the deciding authority and the relevant expertise. This combination can be given by the transfer of knowledge and the transfer of decision rights. Given the impossibility of fully transferring expertise to the decision maker, most decision rights must be delegated to those having specific knowledge. This involves in developing control systems to reduce agency problems. Jensen and Meckling (1995, p.273):

> "Organizations solve these problems by establishing internal rules of the game that provide:
>
> 1. A system for partitioning decision rights out to agents in the organization.
> 2. A control system that provides:
>   (a) a performance measurement and evaluation system;

(b) a reward and punishment system."

Organizational efficiency therefore comes from the combination of these two systems. However, it is impossible to eliminate agency problems.

Then, the principal incurs costs to align the agent's interests to your own. Such costs are called agency costs that can be understood as "cost of distrust". Jensen and Meckling (1976) define agency costs to the sum of the monitoring expenditures by the principal, the bonding expenditures by the agent and the residual loss.

Jensen and Meckling (1976) agency costs emerge in any situation involving cooperative effort between two or more people, even if there is a clear principal-agent relationship. It is noteworthy that the definition of Jensen & Meckling agency costs (1976) is very similar to the problem of neglect and monitoring of a production team raised by Alchian and Demsetz (1972) in a work on the firm theory, for which the contractual structure emerges as a means of increasing team efficiency.

As a solution to minimize the problems of the agency, Jensen and Meckling (1976) suggest: audits, monitoring systems and formal and informal control, budget constraints, incentive system (in order to bring the interests of the agent to the principal), contractual restrictions etc. All mechanisms, of course, involve agency costs. Jensen (1993) adds that there are four control forces operating on the corporation that minimize agency problems. In addition to internal mechanisms, which he calls internal control system headed by board of director, there are external mechanisms (linked to exogenous factors to the organization): capital markets, legal/political/regulatory system, and product and factor markets.

It sums up this theoretical route on agency theory, arranging the concepts discussed here, in Image 3.2.

Summarizing, the agency theory concerns the relationship between the agency, in which the principal hires the agent to perform something that involves decision-making and delegating authority to the agent by the principal, given the agency relationship. Also that there are differences of interests between the principal and the agent because each one have different functions of utility and there is no perfect contract capable of ensuring the interests of the principal (such a situation is called agency problem). As a result the principal incurs costs to align the interests of its agent (such costs are denominated agency costs). In addition, the knowledge necessary for making different decisions is dispersed among several agents and there is knowledge transfer costs among agents. All of this involves developing internal and external control systems to reduce agency problems.

In addition, Jensen and Meckling (1976) say that the agency problem is generalized:

> "The problem of inducing an 'agent' to behave as if he were maximizing the 'principal's' welfare is quite general. It exists in all organizations and in all cooperative efforts—at every level of management in firms, in universities, in mutual companies, in cooperatives, in governmental authorities and bureaus, in unions, and in relationships normally classified as agency relationships such as those common in the performing arts and the market for real estate." (Jensen and Meckling 1976, p.309–310)

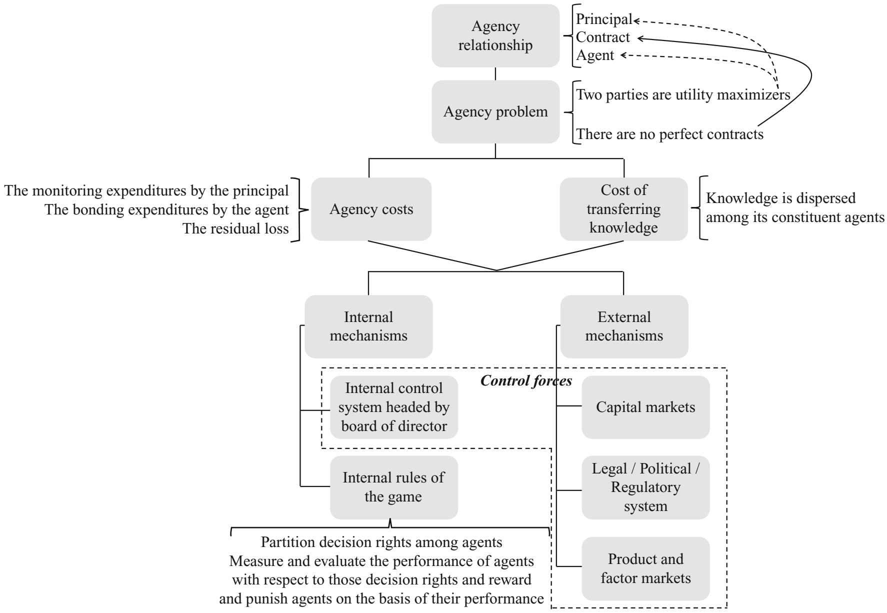

Image 3.2 Mind map—agency theory. *Source*: According to Jensen and Meckling (1976), Fama and Jensen (1983), Jensen (1993) and Jensen and Meckling (1995)

Therefore, this concept can be extended to partnerships related to the triple helix—and its consequences quadruple helix, quintuple helix and N-tuple helix—as the agency problem is not limited only to situations in which it is observed a hierarchical relationship between principal and agent, but are present in all activities involving cooperation ties, even if there is a clear principal-agent relationship.

3.4 Governance

As a general term "governance" refers to govern. Within the context of agency theory, the governance issue comes up in order to mitigate the agency problem. It has been seen that from the perspective of agency theory governance as a set of internal and external mechanisms to soften the derivative agency conflict of separation between ownership and management of organizations. Good governance practices convert principles into objective recommendations, in order to preserve and optimize the value of the organization, contributing to its longevity.

The organization for economic co-operation and development (OECD)—international organization composed of 34 member countries—defined governance principles from the recommendations from stakeholders, regulators and committees set up by other groups, making it an international reference. These principles are clearly adhering to agency theory:

- accountability (the principal and agents shall report and be held responsible for their acts and omissions)
- disclosure (refers to the transparency of actions. More than the obligation to inform, it is the wish to make the information available to all stakeholders and not just to those imposed by laws and regulations)
- compliance (it is about the respect to conformity of regulation norms and to ethics)
- fairness (shown by the egalitarian treatment among the principal and all other stakeholder)

The principles of governance, even if established in the organization, may not materialize into concrete actions. For this reason it is developed governance mechanism so that these principles are instrumented.

As already noted (Sect. 3.3), Jensen (1993) classifies governance mechanisms as external and internal. The external are bound to exogenous factors to the organization, subject therefore to the economic, social, cultural, etc.: capital markets, legal/political/regulatory system, and product and factor markets. And the internal refer to prescribing initiatives, monitoring and endogenous control the organization, therefore, subject to greater control. What Jensen (1993) generically called the internal control system headed by board of director.

The governance framework proposed refers to internal governance mechanisms, in place of external as it was not designed for a context in particular, but in general terms.

In this thread you need to initially align the governance concepts usually associated with corporate governance, partnership, as the principal-agent relation is more complex than when discussing governance in an industry, as the partnership involves the least two institutions, which can set in intrasectoral or intersectoral partnerships (bi or tri-sectoral). This way, governance can generally be understood as a process that aims to harmonize the different interests between the parties so that they can develop cooperative actions.

Making it clear that the governance framework was modeled for organizations that emerge from partnerships in triple helix context, structured as a spin-off, business incubator, accelerator companies, science park among others (organizations emerging from the triple helix interface zones). This way, the agency relationship, takes on the role of principal as being the partner organizations and the agent as the organization interface that run the partnership object.

In order to avoid the creation of a panacea in developing the framework (that would be overly simplistic or burdened with long lists of variables and conditions) approached this dilemma by identifying a relatively small number of dimensions in which the components are postulated to work in an integrated manner to produce outcomes (actions and impacts) and, therefore, turn adaptation. The framework is designed in two governance drives, which make up what is called governance throughput: the macro-structure of power and the intermediary organization management macro processes (see Image 3.3).

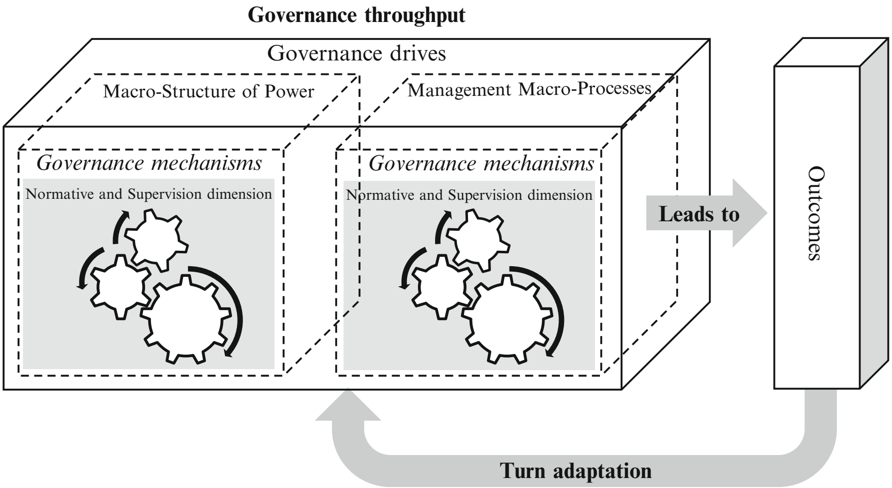

Image 3.3 Conceptual model

3.4.1 Macro-Structure of Power

The power macro-structure refers to the deliberative bodies (board of directors), supervisory (auditing board and external audit), supporting (assisting committees to the board of directors) and executive, and the way these instances are related.

When it comes to partnerships in which emerge intermediary organizations such as executing, the macro-structure of power must be in accordance with applicable law and withhold instances that are out of the executing organization, such as contractors and intervening actors, as well as internal power instance.

Shown is the macro-structure of generic power (see Image 3.4), whose morphology is segmented into four levels—according to the agency theory: principle (those for which the results achieved should meet the interests, by maximizing the resources invested), contract (instrument establishing the agreement of wills between the parties, establishing the regulation of interests), governance mechanisms (dimension aimed at coordinating the principal-agent relationships in order to minimize agency problems, and that is overloaded with agency costs) and agent (in this context the intermediate organization that emerged from the partnership within the triple helix).

- Instances out of the organization
  - Partner (principal): approve the outcomes that are object to the partnership and elect members of the board of directors and audit.
  - Participants/Players: work together or complementary, adding efforts and qualifying results.

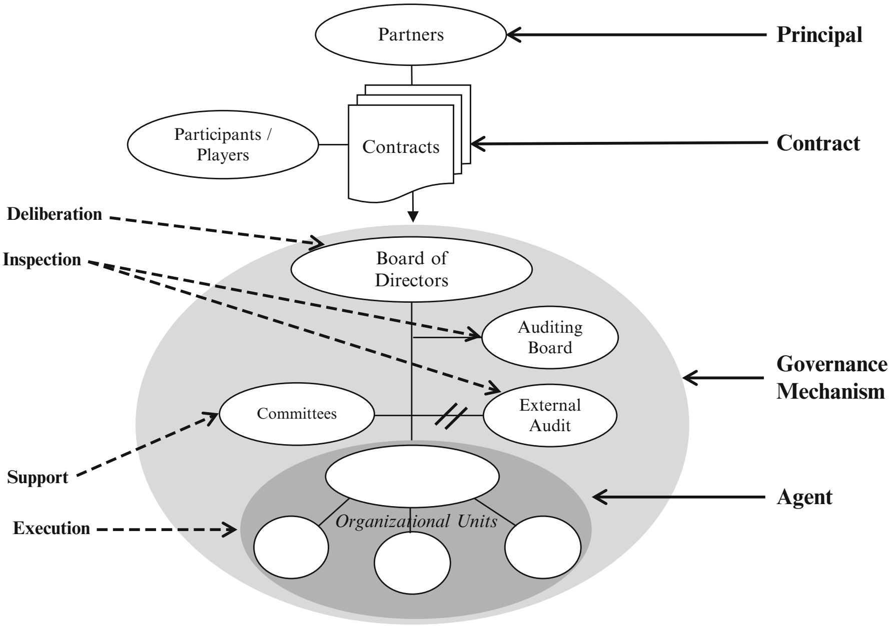

Image 3.4 Generic macro-structure of power

- Notice that it is not done the identification of partners and participants/players, even if the typology of its legal constitution, as the proposed framework is broad and open to interpretation in each particular case.
- Deliberative Body
  - Board of Directors: it is a collegiate body of deliberation composed of members from all parts of the partnership (who are given power), constituting a link between cause and management, being generally composed of a president, vice president, general secretary and directors. Its main objective is to minimize problems and agency costs.

For the configuration of a board it must be observed that in addition to their duties, its size and composition.

The size refers to the number of board members. Jensen (1993) states that boards with high numbers of members tend to be less productive and less likely to be "controlled" by its chairman. On one hand if a large number of members show difficulties to reach reconciled conclusions due to different opinions, a small number limits the variety of opinions, based on the experience and qualifications of its members, so that it might have less qualified decisions. Jensen (2001) suggests between 7 and 8 members for a more efficient performance. Naturally, the desirable size depends on the size and complexity of the organization, among other factors.

Composition regards to the independence or otherwise from its members, who can therefore be internal (directors linked to the organization they represent, such as directors or employees) or independent (external directors with no ties to the organization they represent). Fama and Jensen (1983) and Jensen (1993) support the point of view that independent directors restrict the expropriation possibilities of the wealth from the main agents. The board of directors oversees the actions of management and agency theory show that there is a risk the agent does not act in accordance to the interests of the principal. In this sense it is desirable that the board composition be given to internal and independent members and members who have experience of diversity and qualifications in order to have a balance in its composition.

Another relevant aspect has to with the possible duality of positions between the chair of the board of directors and the CEO. Agency theory points out that to greater independence for the board of directors, it is desirable that such positions are not occupied simultaneously by the same person, so that there is no overlapping positions. It is clearly identified by the agency theory the distinction of responsibilities between the board and the CEO, being the last to account for its activities to the first.

In a survey conducted by Deloitte in 2013, with 76 Brazilian companies with national and foreign capital origin, with several owners, size (in terms of revenue) and sectors of activity, it was found that 47% of the board members were composed of 3 to 5 members and 29% by 6 to 10. The Brazilian Institute of Corporate Governance (IBGC) suggests between 5 and 11 members (IBGC 2009). According to the same survey by Deloitte, 59% of boards were independent members and 76%, the chairman of the board of directors was not the CEO of the organization (Deloitte 2013). Results in line with the assumptions of agency theory.

To finalize it is important to note that the board is not an executive body of a higher level; the role is not to manage, but demand good management, a task for executives. Therefore, the board of directors focus on the end, leaving to the executive to choose the means to achieve such goal. This guideline lies with the board of directors to set policies that are, in summary, the executive performance limits (what they cannot do). Following this reasoning, one must design a model that divide assignments, leaving to the board of directors to fix the policies without interference in management choices—that are up to the executives.

- Supervisory Bodies
  - Internal

    Auditing Board: it is an inspecting body for accounting and financial management. As for its composition and size, the arguments made to the board of directors are applicable.

  - External

    Independent External Audit: provide a legal opinion on the financial statements in order to ensure maximum transparency of resource allocation, ensuring that the financial statements properly reflect the reality and that they comply with current regulations.

- Supporting Bodies

– Committees: are support and advising bodies, that provide support to the board of directors on specific issues. These committees are made up of members of the board itself, allowing them to perform in greater depth activities that require more time than what is made available at board meetings. Note that it is up to the committees to study the issues within its competence, prepare proposals and submit to the board of directors with a vote suggestion as the committees are assisting and not deliberative bodies. In the survey conducted by Deloitte, already referred to, it was more common committees of people/remuneration (53% imposed and 33% with planned institution for the next two years), ethics (49% and 28%), risk/compliance (46% and 43%), auditing (30% and 23%) and crises (24% and 39%) (Deloitte 2013).

  Such committees are strongly aligned to the agency theory, thus creating a second line of defense to the interests of the principal. It is suggested that committees are composed of independent members, as their action is closely linked to the executive body.

- Executive Body (agent)

  – Organizational Units: intermediate organization that emerged in the environment of triple helix which are performed the executive actions.

3.4.2 Management Macro-Processes

Management macro-process refer to the structure of organizational resources through processes and sub-process in order to achieve the strategic objectives. Management macro-process are divided in 6 dimensions.

1. Identity: ontological plan and organizational operational plan (see Image 3.5).

   (a) The ontological plan corresponds to the mission, the vision and values of the organization. This combination provides support to the operational plan (annual), that may be made up by the partnership objectives, the scope statement composed by the definition of deliverable and partnership out of scope, that will form the baseline for the elaboration of schedule, budget and risks. Both the ontological plan as the operational one are up to the executives to propose and the board of directors approve (this will be discussed later on under the decision making dimension).

2. Guidelines: composed of pre-described codes (such as conduct, ethics, etc.) and complaint policies, human rights, anti-fraud, anti-corruption, remuneration, etc. Such policies are essential tasks of the board in order to regulate and minimize risks, misconduct and excessive compensation for executives of the organization.
3. Processes: operational protocols, such as risk management, purchasing management and contracting, budget and others. Refer to the mapping of processes and routines system.

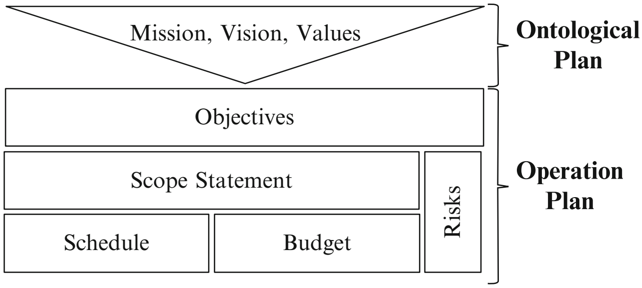

Image 3.5 Identity

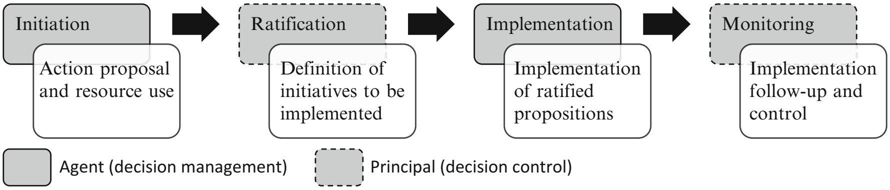

Image 3.6 Decision making. *Source*: According to Fama and Jensen (1983)

4. Communication and information: consists of monitoring reports (operational plan), annual activities, audit, controls, and the disclosure of relevant facts. Reports should be distributed periodically and to different bodies. For example, the external audit usually take place annually and its report is distributed to both the auditing board as to the board of directors; as the financial report (forecast vs. realized) is usually done monthly but it is distributed to boards of directors and auditing quarterly, thus being the chief executive responsibility the monthly monitoring.
5. Decision making: coming back to Fama and Jensen (1983), where it is suggested assigning the stages of decision making "initiation" and "implementation" to the executive team (agent) and the step "ratification" to the board and the step "monitoring" to the board and/or committees (representatives of the principal). See Image 3.6.
6. Supervision and control: verifying alignment of action to the guidelines (2) and processes (3), besides standards and external regulations. Therefore it is pertinent to conduct internal audits, compliance, projects and require follow-up of recommendations.

For all these reasons, governance mechanisms can be seen as a set of restrictions that agents apply on themselves or that the principal apply on agents in order to reduce the risk *ex ante*, monitor the implementation *ex cursum* and evaluate the results *ex post*.

3.4.3 Governance Classification Matrix

It is summarized in Image 3.7 the constituting elements of power macro-structure and management macro-processes previously discussed 3.4.1 and 3.4.2), classifying them as norms (to guide the executives) or supervision (performed by external and internal mechanism to the performing organization aiming at monitoring and controlling their actions)

From this list (Image 3.7) it is possible to classify the governance environment, having the information about the implementation of its mechanisms. A matrix has been made on axis systems where in the abscissas is the mechanism governance supervision dimension, and the ordinates, the normative dimension, generating a squared matrix (2 × 2) that allows to be formulated reasonable assumptions and coherent regarding the current situation of the organization about its governance, as from the dimension of governance mechanism (normative or supervision) generating four quadrants with favorable and unfavorable levels (see Image 3.8).

In the first quadrant all sizes are favorable, with elements of normative dimensions and supervision, possibly in organizations where governance is more mature. In the second quadrant there are elements of the normative dimension that guide the executives actions (agents), however the supervision (performed by the persons elected by the principal) happen insufficiently. That is, although there is guidance on how to proceed, it is not seen in satisfactory way to what extent the guidelines are followed. In the third quadrant all dimensions are unfavorable, meaning it is an organization in which there is no separation between agent and principal or where there is complete trust between the parties themselves or, more likely, in which governance is still embryonic. Then, in the fourth quadrant, there is supervision, but the normative elements that guide executives are not enough, possibly being only informal ones. This way it is likely to have greater deviations between the action of the executive organization (agent) and the wishes of partners (principal) as there is no satisfactory guides to guide the actions of the executives.

3.5 Conclusions

The purpose of this chapter is, in addition to showing the adhesion among the agency theory theme, governance and triple helix, to propose a governance framework for partnerships within the triple helix environment, from the theoretical framework of agency theory—which is one of theoretical subjects most widely used in research on governance. A framework therefore, to allow the management of tensions between agents and principal from complementary mechanisms in order to face agency problems that are not solved only by encouraging typical altruism partnerships in the framework of the triple helix, as warns Jensen (1994, p.45): "[…] even if we could instill more of a spirit of altruism in everyone, agency problems would not be solved. Put simply, altruism, the concern for the well-being of others, does not turn people into perfect agents who do the bidding of others". Therefore, it is necessary to

Drives	Mechanism		Dimensions
Macro-structure of power	Board of Directors		Supervision
		As representatives of parties (principal)	
		Size (between 5 and 11 members)	
		Composed of independent members	
		No function duality President x CEO	
	Audit Council		Supervision
	External Auditing		Supervision
	Administrative Council committees		Supervision
		Personnel/Remuneration	
		Ethics	
		Risk/Compliance	
		Auditing	
		Crises	
		Others	
	Others		---
Management Macro-processes	Ontological Plan		Normative
	Operational Plan		Normative
	Code		Normative
		of conduct	
		of Ethics	
		Others	
	Policy		Normative
		of complaints	
		of human rights	
		Anti-fraud	
		Anti-corruption	
		of remuneration	
		Others	
	Operational Protocols		Normative
		Risk management	
		Purchase and contract management	
		Budget management	
		Others	
	Reports		Supervision
		annual of activities	
		Acivity Follow-up	
		Controls	
		Others	
	Decision Making		---
		Stage Deployment	
		Delegation / Empowerment	
	Monitoring and Control		Supervision
		Internal Auditing	
		Compliance office	
		Project Office	
		Others	
	Others		---

Image 3.7 Prompt list

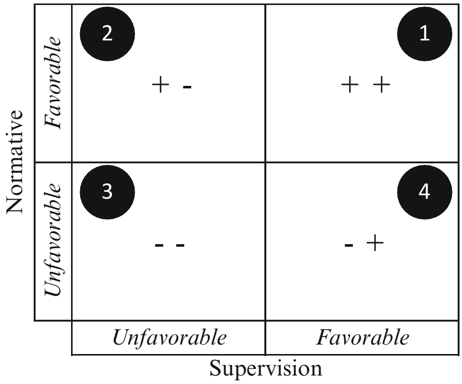

Image 3.8 Classification matrix

institute governance mechanisms that minimize agency problems, noting that such mechanisms, to a lesser or greater extent, overload the burden of agency costs.

Following this, it has been proposed a governance framework based on two drives, which make up what is called governance throughput: the macro-structure of power and the organization's management macro-processes. However, it is not to be understood that there are measures that can be standardized and imposed. A set of guidelines have been organized, not as a "recipe", but as a body of knowledge.

It has also been composed an array of governance environment classification, based on the information about the implementation of governance mechanisms in the normative and supervisory dimensions, creating four quadrants with favorable and unfavorable levels of each dimension of governance drives.

Thus, the chapter focused on agency theory's contribution to the governance of new organizational forms emerging from the platform formed in the triple helix context. It is noteworthy, however, that solving the agency problems in all of its complexity remains to be a challenge to be overcome. This study, despite its relevance, may be considered as an effort to address the issue as it does not predict optimal decisions about key issues in governance (accountability, disclosure, compliance and fairness), but lists mechanisms, with secure theoretical foundation, that can mitigate the agency problems. Hopefully it may contribute to better understanding the governance environment in partnerships within the triple helix, enhancing the debate on the theme.

As a suggestion for future research, it is suggested to research governance in an inter-organizational arrangement, thus requiring a theoretical reformulation to consider the differences between the levels of intra-organizational partners, and the principal-agent relationship not being present in the partnership itself, manifesting therefore differently in each type of partnership and partner organization in the triple helix context. While in companies there are mechanisms similar to these discussed in this chapter, in the university and government sphere this happens under other theoretical base. Thus, the proposed drives must be reformulated according to the types of partner. This implies on discussion over who is the principal and who is the agent in each of these organizations and how the normative and supervisory dimensions are seen and then explore the convergences and divergences. Then a discussion on the agency relation in the context of the triple helix in partnerships where interface organizations do not emerge.

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Chapter 4
Revisiting the Triple Helix Innovation Framework: The Case of Abengoa

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Abstract The Triple Helix (TH) model is an analysis framework in which universities act as key drivers of regional innovation development in knowledge-based societies. The TH model describes interactions between three actors—university, industry, and government. Most empirical studies have addressed the role of universities, choosing to adopt a macro perspective rather than a firm perspective. Thanks to the TH model's theoretical potential, studies using the TH framework have greatly contributed to our understanding of the dynamics and interactions among these actors. Nevertheless, this framework still contains gaps such as determining the value and practical implications of the role of firms in the TH model. This research challenges the TH literature's traditional emphasis on the university as the main driver of innovation by addressing the following research question: Is the university really the main driver of innovation, or does each of the three helices play this role at some stage of the innovation process? Hence, this study examines the applicability and practical value of the TH model when exploring business creation, business growth, and firms' contribution to regional innovation development. The study also explores firms' interactions with universities and governments at the European, national, and regional levels. Specifically, this exploratory study examines the case of Abengoa, a multinational leader in renewable energy industry, specializing in innovative, sustainable biotechnology and biochemistry solutions.

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4.1 Introduction

The innovation literature explores how diverse actors and institutions promote and spread innovation. Research in this field has gradually broadened its scope to cover a wide range of actors. The Triple Helix (TH) framework builds on the assumption that interactions among academic institutions (universities and other public research organizations), industry, and government (local, regional, national, and supranational) is the key to fostering regional innovation and growth within the current knowledge-based society (Etzkowitz and Leydesdorff 2000). The TH model serves as a platform to analyze dynamics and organizational forms in terms of increasing regional innovation and to enhance the innovative capacity of firms through collaboration with knowledge institutions, government, and other public agencies (Ranga et al. 2008). The three helices are partly independent yet partly interdependent. Thus can also play the role of one of the other entities (Ranga and Etzkowitz 2010). Several countries have embraced the TH framework to generate more innovative regions and encourage business creation.

Nevertheless, the TH model is just one of several approaches to addressing innovation dynamics in different contexts. For instance, systemic approaches, such as cluster theory (Porter 1990) and the regional innovation systems framework (Asheim et al. 2011), depict the firm as the leader of the innovation process. Conversely, Sábato's Triangle (Sábato 1975) presents the state as the main actor. The TH model emphasizes the role of universities as drivers of regional innovation (Etzkowitz and Leydesdorff 2000). Although scholars have confirmed the theoretical value of the TH model, some unanswered questions remain. How do the three helices actually interact during each phase of the innovation process, and who are the key actors within each phase? How are the relationships established during the different interactions? What are the main drivers in each interaction? How do the interactions evolve over time? At what stage is the interaction between the university and industry helices most successful? What can be considered a successful outcome of these interactions?

Empirical research has provided a better understanding of the interactions between actors in specific regions or sectors and has expanded the TH framework's theoretical potential. Yet research on the usage of the TH framework as driver of innovation development traditionally tackles the issue from a macro perspective (Brännback et al. 2008) rather than from a firm-level or entrepreneurial perspective. This study challenges the dominant logic by posing the following research question: Is the university really the main driver of innovation, or can each of the three helices play this main role at some stage of the innovation process? From a firm-level perspective, this chapter sheds light on the applicability and practical value of the TH model by exploring the role of each helix and the way it interacts with other helices. To study this issue, we tested the TH model at each stage of Abengoa's innovation process.

Abengoa is a Spanish multinational founded in 1941 in Seville (southern Spain), where it remains headquartered. Abengoa defines itself as "an international company that applies innovative technology solutions for sustainability in the energy and environment sectors, generating electricity from renewable resources, converting biomass into biofuels and producing drinking water from sea water."[1] The empirical analysis in this chapter is qualitative, consisting of a case study of Abengoa. The aim of the analysis was to obtain information concerning Abengoa's, structure, growth, and interactions with universities, research groups, and government entities. The analysis followed three steps. We first reviewed the literature on the TH framework and its applicability. Second, we performed a series of semi-structured interviews with a key informant with broad experience at Abengoa. Third, we assessed the information gathered from these interviews and data provided by Abengoa.

Results reveal the value of revisiting the TH framework from the firm-level perspective, yielding implications for innovation policies and management in peripheral regions. This case study provides further insight into the interactions among the three helices, thereby filling some gaps in the TH framework. By applying the TH model to Abengoa, we not only verified the model's applicability from a firm-level perspective, but also identified the drivers of innovation in each helix and determined which actor leads each phase of the innovation process in a specific economic sector or region.

The chapter has six sections. Section 4.2 presents the conceptual framework and explains the TH model. Section 4.3 describes the method. Section 4.4 presents the findings of the case study. Section 4.5 discusses these results. Section 4.6 offers conclusions and implications at both academic and managerial levels.

4.2 Conceptual Framework

Using an interactive approach, Etzkowitz and Leydesdorff (1998, 2000) developed an analytical framework, which they named the Triple Helix (TH). This model is a sociological complement as it combines the institutional assessment of the innovation process with the evolutionary analysis of the knowledge economy (Etzkowitz 1994; Leydesdorff and Meyer 2006). To understand the complexity of the innovation process dynamics, these authors assume that innovation arises from the mutual interaction between three propellers or key actors: (1) the university, which has the potential to generate scientific knowledge; (2) the industry, which provides economic resources and market potential to absorb such new knowledge as innovations; and (3) the government, which sets standards and policies to offer innovation incentives (Etzkowitz and Leydesdorff 2000).

Metaphorically speaking, these interactions emulate the structure of DNA, shaped by three helices of the same chain. By co-evolving and coordinating with one another, these three helices represent the complexity of the innovation process (Etzkowitz 2003). The mutual interest in generating knowledge and innovation arises from the communication, networks, and organizations generated through reciprocal relationships among the helices. The TH framework provides a foundation for understanding innovation processes, with the three helices interacting in such a variable way that

[1] See http://www.abengoa.com

sources of innovation raise a puzzle that agents, organizations, and policymakers must solve (Etzkowitz and Leydesdorff 2000). Thus, the TH framework depicts a constantly changing innovation system whose helices evolve by interacting with other helices. By switching roles, the three helices perform functions that transcend their traditional duties. For instance, industries may engage in scientific research, and researchers may launch companies (González de la Fe 2009).

The TH framework illustrates how the helices relate to one another through instability and continuous reorganization and harmonization of the innovation process at different levels—local, regional, national, and supranational—and across different components of the economy—markets, sectors, and systems. One assumption of the TH model is that universities, the government, and industry within a specific context foster economic growth by building enduring "generative relationships" (i.e., reciprocal relationships) that change the way agents conceive their environment and the way they act within it (Etzkowitz and Leydesdorff 2000). The ability to control these dynamics, however, is relative. This does not mean, for example, that the government ceases to hold that role, but rather that the government must act to promote opportunities and align itself with the other two helices (i.e., university and industry).

In the TH framework, the university is the key strategic actor in the innovation process. Etzkowitz and Leydesdorff (2000) posits that, in addition to its two traditional functions of teaching and research, the university performs a third activity fostering entrepreneurship and encouraging the innovative development of the socio-economic environment. This "third mission" involves all activities related to generating, using, applying, and exploiting, outside the academic sphere, all the university's knowledge and skills (Molas-Gallart et al. 2002). Thus, students are potential innovative agents because of their contribution to the flows of human capital and the dynamism of the research groups toward the productive sector, which ensures that the university remains a primary source of innovation (Etzkowitz and Leydesdorff 2000). Compliance with the third mission makes the university a key contributor to economic and social development through closer ties with agents in the university's environment.

Several studies have applied the analytical scheme of the TH, which is proposed as a model that enables empirical measurement. Rather than adopting a firm-level perspective, most empirical research adopts a macro perspective to address the role of universities and study government strategies designed to promote interactions through new rules of the game. Some of these empirical studies focus on the role of specific universities and their relationships with industry and government (Bramwell and Wolfe 2008; Etzkowitz, et al. 2012). Others analyze the dynamics of interaction in a certain national or regional context (Fiore, et al. 2011; García-Aracil and de Lucio 2008) or in a particular sector (Arbuthnott and von Friedrichs 2013). Focusing on empirical analysis of the renewable energy sector, few studies explore the dynamics of innovation within the TH framework, mainly centered on the innovation process of a specific region or on the role of the energy policy (Klitkou and Coenen 2013).

The TH framework has attracted several criticisms. First, it is a normative-oriented perspective, which favors some kind of successful examples and attenuates the conflict of interest, as it predominantly embraces commonality and consensus among stakeholders. The TH framework understands that the three helices may develop conflicting relationships, which can lead to unexpected or undesired consequences. Second, in the TH model, the role of the industry helix is less well developed than the roles of the university and government helices (as drivers of innovation). Few empirical studies place industry at the heart of the model. Nevertheless, Etzkowitz (2008) and Steiber and Alänge (2013) highlight empirical cases where the firm—Saab Aerospace and Google, respectively—is the key actor in TH cooperation with the government and a local university. Other studies focus on challenges and opportunities for enhancing the innovative capacity of small firms through TH interaction (Ranga et al. 2008).

Finally, the TH model theory contains gaps regarding our understanding of innovation dynamics among the main actors at the micro level. Most TH studies adopt a macro perspective to analyze how universities interact with the other two helices. From a micro perspective, Leydesdorff and Etzkowitz (2003)) argues that the TH framework can be analyzed in conjunction with other complementary perspectives, including the neo-institutional and neo-evolutionary perspectives. These gaps raise some unanswered questions. Does each helix perform only the function it is assigned according to the classic TH framework, or do the helices switch their roles among themselves? How do the actors define their strategies in the innovation process? What resources do they mobilize? And what conflicts of interests emerge during these interactions? These questions can be used as a basis to expand the TH model. For example, the local/global perspective could be added as a fourth helix to reflect the potentially important role of internationalization (Leydesdorff and Etzkowitz 2003). Alternatively, society or the public could be added as a fourth helix. These additional helices may be relevant in terms of different "horizons of meaning" for the interacting agents and institutions. In a study of the Green and Gene Revolution, however, Parayil (2003) found that, although certain societal agents contributed to the innovation network, they did not become sufficiently autonomous to be categorized as a fourth helix.

4.3 Method and Empirical Context

This study uses a qualitative method, consisting of a case study of the multinational firm Abengoa. The aim of the analysis was to obtain information about Abengoa's structure, growth, interactions with research groups at universities and public research organizations (PROs), and interactions with government agencies (European, national, and regional). Case study research is useful for expanding and generalizing theories by combining theoretical knowledge with new empirical insights (Yin 1994).

We chose Abengoa because of its profile and location. Abengoa is a multinational firm founded in 1941 in Seville (Spain), where it remains headquartered. Despite Abengoa's roots, the firm's core activity today is the manufacture of solar panels across Andalusia (a region in southern Spain). Abengoa is currently among the 35 biggest firms in Spain. A world leader in solar power technology, Abengoa has received worldwide acclaim for its work in many renewable energy and environmental industries, including biofuel production and water solutions. Abengoa describes itself as "an international company that applies innovative technology solutions for sustainability in the energy and environment sectors, generating electricity from renewable resources, converting biomass into biofuels and producing drinking water from sea water" (Abengoa website). Abengoa operates in the energy and sustainability market, focusing on renewable energy and environmental solutions.

Today, Abengoa is an international company with a presence in more than 80 countries, predominantly in Europe, North and South America, Africa, and the Middle East. Pursuing an active strategy of internationalization, Abengoa continues to expand into key markets such as the US, China, India, and Brazil—in part, to counter the effects of the latest economic crisis, which has severely affected the Spanish economy. Nevertheless, the company still has a strong presence in Spain, although the economic crisis has forced Abengoa to abandon or delay several important projects to develop renewable energy infrastructures in Spain. Together with internationalization, the two pillars that shape and sustain Abengoa's success are innovation and technology. Abengoa's commitment to innovation and R&D has driven the company's growth since Abengoa was founded and is one of the main reasons for its progressive market and geographic diversification. This commitment to innovation and R&D is the main reason why Abengoa offers such a valuable case study.

Abengoa's headquarters is in Andalusia, a peripheral region in Southern Europe. Table 4.1 shows R&D indicators for Andalusia, Spain, and the European Union (EU). Figures for R&D expenditure and the number of R&D employees in Andalusia are lower than the Spanish and EU averages. Moreover, most R&D expenditure is in the public sector; the business sector represents 34.5 % of R&D expenditure in Andalusia, compared to 51.5 % in Spain and 64.0 % in the EU. Traditionally, service and construction SMEs dominate the Andalusian business sector. [2]Hence, Andalusian innovation intensity is weak and is based on low and medium-level technology sectors with limited innovation investment capacity and low absorptive capacity.

We collected the data for our case study using a combination of primary sources (qualitative technique: interviews) and secondary sources (annual reports, project data, R&D budget data, and the corporate website). We conducted the interviews at Abengoa in 2015. The Abengoa management assigned us a key informant who has held various positions at Abengoa in different product areas and regions. The interview was semi-structured with open-ended questions. The aim of the interviews was twofold: to understand the organizational characteristics and development of Abengoa's innovation model and to learn how Abengoa interacts with universities, governments, and industry. The interviewees had different levels of knowledge and experience about how Abengoa was created and developed its innovation model through interactions with other actors. The interviews were digitally recorded and then transcribed. Finally, we analyzed data from the interviews using a grounded-theory approach (Symon and Cassell 2012). We then categorized these data according to three helices: university, industry, and government.

[2] The service sector represents 62.0 % of Andalusia's GDP. The construction sector (10.8 %), manufacturing (9.0 %), agriculture, farming, and fisheries (6.1 %), and energy (2.4 %) are the four next biggest industries in Andalusia in terms of GDP (INE, Regional accounts, 2007)

Table 4.1 Main indicators of R&D and innovation in Andalusia, Spain, and EU27 (2007)

	Andalusia	Spain	EU27
Gross expenditure on R&D (GERD) (million euro)	1,538	14,701	214,746
GERD as a percentage of gross domestic product (GDP)	1.03	1.35	1.96
Total R&D employment per thousand total employment	7.6	10.6	11.9
Total R&D researchers per thousand total employment	4.6	6.5	7
Percentage of GERD performed by universities and public administration	65.5 %	48.5 %	36.0 %
Percentage of GERD performed by the business enterprise sector	34.5 %	51.5 %	64.0 %
Innovation intensity in firms[a]	0.72	0.89	- [b]

[a]Innovation intensity in firms = (Gross expenditure on innovative activities/turnover) × 100
[b]Data are unavailable for EU27 (2007)

Sources: INE and Eurostat

4.4 Empirical Findings

4.4.1 A History of Abengoa's Innovation Model

In 2011, Abengoa identified the need to create a new business area, Abengoa Research (AR). Until then, each of Abengoa's business groups—solar, water, bioenergy, etc.—conducted its own R&D. AR's aim was to integrate Abengoa's R&D operations. AR started with about 50 professionals, most of whom were university researchers lacking experience in the private sector. Abengoa appointed Professor Manuel Doblaré, from the Univeristy of Zaragoza, as Scientific Director and Head of AR. Initially, AR resembled a University department or research area more than a company. This has gradually changed as AR has become more important at Abengoa—in terms of budget, staff, and remit.

Initially, AR exclusively performed exploratory R&D to formulate a 10-year plan for Abengoa's technological advances and innovations. Today, however, AR also performs R&D that already targets an existing market demand and a set of customers to meet and satisfy. AR has grown in size and scope, and it now has three branches. (1) Corporate/staff: deals fundamentally with human resources, finances, administration, legal services, and the Patent Office. (2) R&D: covers tasks ranging from performing basic research to developing innovations, patents, and prototypes. (3) Innovation and consultancy: seeks to improve innovation processes and products. Before the creation of AR, each business line within Abengoa had its own R&D strategy and policy. After 2011, however, AR began performing all of these roles. AR offers a support function for the other business groups, performing the R&D activity for the entire firm. AR's role is to validate new technology at a lab or demo scale. AR does not manage to show it to the market; its function is limited to checking that such technology works but does not guarantee it in a market perspective. AR does not deal either with financing R&D projects. These issues are the responsibility of the other business groups.

Within this organizational model, Abengoa follows the "stage-gate" method for the innovation process. Stage-gate is a widespread system for launching new products. Numerous firms have adopted stage-gate in conjunction with open innovation (Cooper 2008). Stage-gate works as follows. First, an innovative idea arises. Then, depending on how close this novel idea/technology is from being marketed or commercialized, it will be placed in a certain phase. Stage-gate has five phases: (1) basic or preliminary research, (2) advanced research, (3) design of the prototype, (4) pre-commercialization, and (5) commercialization. This method is useful for assessing the firm's R&D involvement and endeavor. The gates in stage-gate mark key decision points where the firm decides whether to continue or abandon the project. Each gate thereby opens or blocks the path to the following phase of the innovation process.

To explain Abengoa's innovation model, we first describe one of Abengoa's key successful innovations: PS10. In 2007, Abengoa built the first saturated steam plant in the world—PS10—in Sanlúcar la Mayor (Seville, Spain). This plant was a milestone—an example of disruptive innovation. In 2009, Abengoa developed PS20, a new plant that practically doubled the power output of PS10 and substantially improved on PS10's performance, incorporating both technical and operational improvements (incremental innovation). Next, Abengoa designed a superheated steam prototype. The prototype became operational and financially viable (validated by a bank). Abengoa launched the prototype, under the name KHI, as a commercial plant in South Africa. These three plants—PS10, PS20, and KHI—offer good examples of how Abengoa strategically focuses on innovation, both disruptive and incremental, to remain competitive and become a leader within its sector.

4.4.2 The Role of the Three Helices in Abengoa's Current Innovation Model

The three helices (i.e., university, industry, and government) all play specific roles in Abengoa's current business operations. After making some general comments, we examine each of the three helices in turn.

a) **Industry interactions**

Abengoa differs from any enterprise that faces competition in the national market. Abengoa stands out as a leader in the Spanish renewable energy market, but it is also among the leaders of the European solar thermal energy and bioethanol markets. In Andalusia (southern Spain), where Abengoa is headquartered, industry is scarce, and SMEs are the most common type of company. Thus, Abengoa is like an oasis in the desert, although it is surrounded by a thriving auxiliary industry. These auxiliary firms, which have developed around Abengoa, frequently establish alliances and sign collaboration agreements with Abengoa. Governments tend to award grants that foster or enhance a region's development in a certain industry or activity—we discuss this issue in depth in the section on government interactions. A condition of these grants is that applicants must present applications in consortium with one or two

SMEs, hence creating a tractor effect. By virtue of the government's strategy of subsidizing this industry, SMEs that would never otherwise consider participating in large projects have the chance to collaborate.

b) **University interactions**

Abengoa collaborates intensively with many universities as well as with public and private research organizations. Table 4.2 presents the main universities and research centers that collaborate closely with Abengoa. Most of them are Spanish, but some are located beyond the Spanish boundaries, in Europe and North America. Early collaborations took place with universities and research centers in the same region. When Abengoa began to expand and its need for highly specific knowledge increased, however, these collaborations spread to specialist research groups abroad. Table 4.2 presents a subset of the firms with whom Abengoa collaborates. Figure 4.1 shows a map of Abengoa's network of collaborations with these institutions around the world.

Abengoa has traditionally had a broad network of links with universities, research groups, and institutions. Consequently, in May 2015, when this study was developed, the firm supported 33 research internships and 16 students. Furthermore, 87 of Abengoa's employees held PhDs.

c) **Government interactions**

Governments interact with Abengoa through four mechanisms: (1) grants, (2) tax incentives, (3) feed-in tariff, and (4) patent box.

1. Grants: During the initial stages of the R&D process, governments may seek to attract technologies to their region (pull strategy by the government). Usually, governments do so through grants. Grants can be regional, national, or European. They are of two types: (1) non-competitive or "open window" and (2) competitive. Non-competitive grants guarantee that a minimum amount of public funding goes toward research. These grants support companies' ongoing R&D operations. In contrast, competitive grants have fixed deadlines for call and delivery of projects, and their incentives tend to be larger than those of non-competitive grants. Competitive grants often require the applicant to apply in consortium with one or two SMEs and a research group from a university or research center, thereby creating a tractor effect. Thus, SMEs that would never otherwise think of working on a project with Abengoa can collaborate. Grants are a direct financing method and are unsustainable. In the US, Abengoa also receives grants from the Department of Energy (DOE).
2. Tax incentives: Firms might also benefit from tax incentives by carrying out R&D, regardless of the research area or size of the project. The advantage of tax deductions over grants is that, although the firm must show it has carried out the R&D, it has no obligation to present any findings. Thus, firms must give evidence that they have undertaken the R&D, but not that they have achieved any outcome. The person or committee responsible for certifying that the company has performed the R&D bases the decision on implementation rather than results.

Table 4.2 Abengoa's main collaborations with universities

Context		University
Regional		1. Universidad Loyola Andalucía
		2. CSIC—Instituto Científico Materiales Sevilla
		3. Universidad Pablo Olavide
		4. Universidad de Sevilla
		5. Universidad de Málaga
		6. Universidad de Granada
		7. Universidad de Cádiz
		8. Universidad de Córdoba
National		1. Universidad de Zaragoza
		2. Universidad Politécnica de Cataluña
		3. Centro Internacional de Métodos Numéricos en Ingeniería
		4. Universidad de Castilla la Mancha
		5. CSIC—Instituto Ciencia Materiales Madrid (ICMM)
		6. Universidad de las Palmas de Gran Canarias – ULPGC
		7. Fundación Universidad de Oviedo
		8. Universidad Complutense de Madrid
		9. FUAM—Fundación Universidad Autónoma de Madrid
		10. Universidad Politécnica de Madrid
		11. Universidad La Laguna
		12. Universidad de Cantabria
European	Germany	1. Universität Technische München
	Germany	2. HZDR—Helmholtz Zentrum Dresden Rossendorf
	United Kingdom	3. University of Cranfield
	Switzerland	4. Ecole Polytechnique Federale de Lausanne
International	United States	1. University of Oklahoma
	United States	2. Real Colegio Complutense At Harvard Executive Program
	United States	3. University of California—Berkeley
	United States	4. University of Illinois
	Mexico	5. Universidad Nacional de México

Source: Compiled by the authors using data from Abengoa

3. Feed-in tariff: It applies to projects on a commercial scale, thus it is not a pure incentive R&D. Spain has a legal Feed-in tariff, which guarantees that all of the firm's production will be sold at a fixed price. Such a policy allows firms to plan their investment because they can guarantee the income they will obtain from sales. Therefore, across the feed-in tariff, the government can encourage the creation of a market or guaranteeing the existence of a demand.
4. Patent box: A patent box is a tax incentive that rewards innovation and encourages firms to create and exploit patents and new designs. This incentive works by reducing income tax for certain intangible assets developed by the company. The firm then sends the manufacturer of the plant an invoice which is partly tax-exempted and involves two descriptions. These two descriptions are know-how and transfer of use and technology.

Fig. 4.1 Map of Abengoa's main collaborations with universities. *Source*: Compiled by the authors using data from Abengoa

4.5 Discussion

By studying the case of Abengoa, we have identified several interaction mechanisms in the TH framework. We can highlight the key role of the firm in involving the other helices, thereby contributing to fostering interactions. This exploratory study improves our understanding of the interactions within the TH model. The study shows that interaction spaces are broader and more complex when the firm-level perspective is adopted. This finding enriches the TH framework. The main practical implication of this study is that it highlights the role of the firm within this triple interaction on the path to a more competitive and innovative development of a certain environment. Figure 4.2 summarizes our findings, illustrating the dynamics of the interactions in the TH model applied to Abengoa's innovation process. The model reveals the importance of each helix throughout Abengoa's innovation process.

Note:

INDUSTRY: To access government grants, firms must align themselves with one or two SMEs, thereby creating a tractor effect.

UNIVERSITY: In the early phases, the university has the leading role. In phase 3, industry has the leading role. In phases 4 and 5, the university's influence is non-existent.

GOVERNMENT: Grants, tax incentives, patent box.

Figure 4.2 suggests that the government is influential during all phases of the innovation process, although its influence varies. In phase 0, universities and research centers are the only actors with knowledge of the topic. In phase 1, the company begins to learn, and then in phase 2, this tie becomes much more balanced. In phase 3, the company becomes significantly more important, and the university becomes significantly less relevant. In phases 4 and 5, the university's

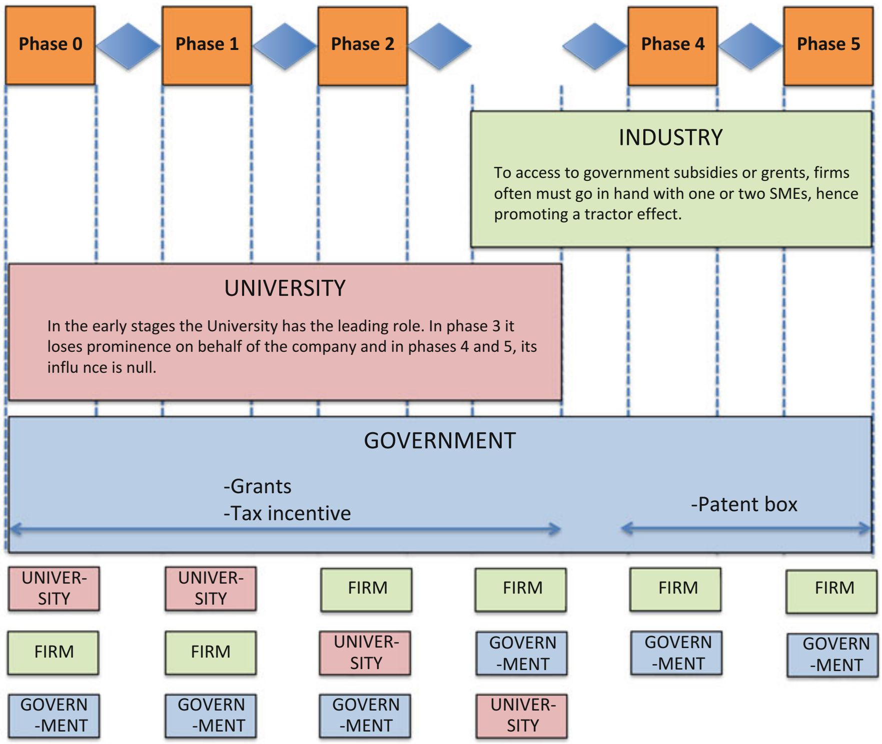

Fig. 4.2 Involvement of each helix during Abengoa's innovation process. *Source*: Compiled by the authors using data from Abengoa

influence is practically non-existent. Thus, the relevance of the university diminishes as the R&D process unfolds. Arguably, the firm becomes the main innovation driver.

4.6 Conclusions and Implications

We should note the following conclusions, implications, and limitations of this study. First, the study's findings might be relevant for refining empirical approaches using the TH framework. The study reveals some insights to help scholars to probe the role of firms within the TH framework. Unlike most works addressing the TH framework's validity and applicability, this study emphasizes the role of the firm in the innovation process. Whereas most papers on the TH framework present case studies of universities or focus on the development of a particular region, the current chapter adopts an original approach by focusing on the firm. Few studies empirically analyze the TH framework by focusing on the firm. This chapter presents a case study of Abengoa, and, in doing so, adopts a novel approach. Therefore, our analysis contributes to the debate on the relevance and applicability of the TH framework by exploring the actors within the TH framework and the roles they play during each phase of the innovation process.

This study contributes to filling the gaps, noted by Ranga (2011), in the literature on the TH framework. These gaps relate to establishing a better understanding of how the university, industry, and government helices interact with each other; which actor plays a dominant role during each phase of the innovation process; what drives these interactions; how the relationships evolve; and so forth.

The firm appears to play a critical role in the innovation process. Its effect on the success of the innovation process, however, complements the effects of governments, universities, and research institutions. Our findings are therefore consistent with the literature and validate the applicability of the TH framework, regarding its impact on the success and development of the innovation process.

This research nonetheless has some limitations. Working at the firm level causes difficulties in obtaining primary data on interactions among innovation actors. Furthermore, these actors are both structurally and organizationally complex. Hence, this study is predominantly exploratory. It would therefore be interesting to perform further research to reformulate our propositions as research hypotheses and then validate these hypotheses empirically.

4.7 Appendix

Table 4.3 Abengoa's agreements and collaborations with universities and research organizations

Country	Number of agreements
Spain	160
United States of America	10
Germany	8
Switzerland	4
United Kingdom	1
Mexico	1
	Total: 184

Source: Compiled by the authors using data from Abengoa

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Chapter 5
The Role of Triple-Helix Collaboration in the Development of Cleantech Entrepreneurship: Lessons Learned From the Øresund and Moscow Regions

Peter Kiryushin, Bala Mulloth, Tatiana Iakovleva, and Nataliya Ivashchenko

Abstract This study analyzes the role of triple-helix collaboration in two regions—Øresund, the Danish-Swedish cross-border region, and the Moscow region. We focus on the role of the university in stimulating clean technology (cleantech) entrepreneurship. Implementation of cleantech usually assumes an improvement of environmental performance at a lower cost, higher productivity and responsible use of natural resources which could result in more sustainable development of the region. Our comparative research is based on more than 30 interviews and communications conducted between February 2012 and February 2015 with stakeholders from academia and public and private sectors in the regions. The results show that Øresund and Moscow regional innovation systems indeed possess proven capacities for the development of research-based innovations, particularly the cleantech ones. At the same time there are no strong interconnections between university-born innovations and entrepreneurial activities in the Øresund and Moscow regions. The lack of entrepreneurial capacity and culture seems to be a common barrier for triple-helix collaboration to work effectively in both regions. Our findings reveal that in order for innovations in cleantech to be successfully implemented, the efforts of entrepreneurs become essential for promotion of knowledge spillover from research institutes and

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"locked" systems into business environments in order to successfully implement innovations in cleantech. Furthermore, encouraging research-based innovations related to social sciences significantly extends the possibility of building robust regional innovation systems.

5.1 Introduction

Meeting the challenges of the twenty-first century, modern societies promote innovation and entrepreneurship to secure sustainable development (GEM 2014). Universities play a considerable role in fostering innovation activities and spilling new knowledge to the regions (Etzkowitz and Leydesdorff 2000). A triple-helix approach is crucial for understanding the role of knowledge spillover in the context of regional innovation system since it focuses on the role of a university in stimulation of innovation and economic development in a society and researches various formats for knowledge dissemination and application (Ranga and Etzkowitz 2013). The entrepreneurial university takes a pro-active stance in the process of new knowledge implementation and generation. We refer to entrepreneurial university as to the universities that have developed different mechanisms to contribute to regional development and increase their income (Guerrero and Urbano 2010). As universities begin to collaborate, they can combine discrete pieces of intellectual property and exploit this synthesized information. These collaborations with other actors from the innovation field contribute to the diversification of knowledge from universities to the business environment (Leydesdorff and Meyer 2010). On top of this, entrepreneurial universities eventually evolve from educating individuals to educating entire organizations through implementation of entrepreneurship and incubation programmes as well as new training modules at a variety of venues which include inter-disciplinary centers, science parks, academic spin-offs, incubators and venture capital firms. Apart from serving as the pool of new ideas available to existing firms, entrepreneurial universities promote triple-helix collaboration by combining their research and teaching capacities into new formats in order to become a platform for establishment of new firms. Universities increasingly become the source of regional economic development.

One of the promising innovative industries that can boost regional development is cleantech. The term "cleantech" stands for "clean technology", could be defined as "energy and environment-related technologies developed with the objective of reducing harmful effects on the environment" (Swedish Energy Agency 2010). Implementation of cleantech usually assumes an improvement of environmental performance at a lower cost, higher productivity and responsible use of natural resources (Swedish Energy Agency 2010). Clean technology is the niche which unites science and business. There is a variety of difficult socio-economic, environmental and governance challenges including climate change, oil depletion and growing threats to natural resources such as water. While these challenges are generally perceived as threats, they can also constitute new opportunities for clean technologies development (Cleantech Group and WWF 2012). Although the largest part of cleantech focuses on energy innovation, including energy efficiency and renewable energy, there are also other important areas for cleantech such as water, agricultural waste and materials.

Thus, presence of a strong cleantech industry in the regional innovation system (RIS) could significantly contribute to sustainable development of different regions. Cleantech innovations are often research-driven, which is why development of a successful cleantech industry can be often connected to the active university environment in the region (Cleantech Group and WWF 2012). University-driven entrepreneurial efforts are seen as an important precursor for the development of sustainable cleantech entrepreneurship in the region.

This discussion generates the following research question: "What is the role of triple-helix collaboration in the development of cleantech entrepreneurship and in shaping of regional sustainability?"

For the purposes of this study we analyzed two separate regions:

(a) The Øresund, Danish-Swedish cross-border region;
(b) The Moscow region, which includes Moscow and the Moscow Oblast' (administrative unit surrounding the city).

There are several reasons supporting our choice, including: similar intensity of higher education and research institutions, high level of economic development as well as presence of similar universities in both regions,—specifically, Lund University and Moscow State University, which became the central objects in the RISs. In this study, we firstly present our theoretical framework. Second, we describe our research methodology. Third, our findings pertaining to the two regions — Øresund and Moscow — will be presented based on our literature analysis and information collected from the available interview data. To conclude our research, we discuss the identified opportunities and challenges which were experienced during the process of implementation of the triple-helix collaboration framework and draw certain theoretical and practical conclusions.

5.2 Research Framework

In this study, we aim to analyze the role of the triple-helix collaboration and cleantech entrepreneurship in the context of regional innovation system. RISs and their roots represent a widely discussed topic in the academic literature (Asheim et al. 2011; Lundvall 1992). RIS could be described as "a set of interacting private and public interests, formal institutions and other organizations that function according to organizational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge [in the region]" (Doloreux and Parto 2012). In most cases, both theoretical and empirical works have focused on RIS situated within a national context, but in recent years the application of RIS concept was extended to include entrepreneurship elements and debated in relation to cross-boarder settings (Trippl 2006; Lundquist and Trippl 2011).

The RIS approach studies the social interaction of economic actors in a region within localized innovation networks and considers how institutional evolution can produce “constructed advantage” thereby creating regional capacity for improved innovation and economic performance. RIS is most directly concerned with uneven geographies of innovation (Asheim et al. 2011). We adopt the holistic approach proposed by Trippl (2006) and focus on the role of cleantech entrepreneurship and innovations in the cross-institutional collaboration (also known as the triple helix collaboration) between knowledge-generating actors such as academia, knowledge-adaptive actors such as industry, and regional policy subsystems (Trippl 2006; Lundquist and Trippl 2009; 2011; Caniëls and Bosch 2011). The triple helix thesis states that the university can play a progressive role in reinforcing the innovation sphere in increasingly knowledge-based societies (Etzkowitz and Leydesdorff 2000) in comparison with the national innovation systems approach. The RIS approach is more specific in terms of analyzing the structural organization of innovation processes between firms, policy institutions, research organizations and intermediary institutions. In spite of globalization, regional innovation is indeed reinforced by various kinds of agglomeration economies among co-located firms in similar or related sectors alongside innovation support by regional knowledge producers such as universities.

The core concepts of regional innovation systems are rooted in the theory of innovation and, in particular, in the theories of economist Joseph Schumpeter. His views on innovation-related technological changes and entrepreneurship as drivers for economic growth became the basis for innovation policy in many regions (Schumpeter 1934; 1994). Innovations do not originate from the rational thinking process, but rather develop during the creative pioneering process (Hospers 2005). Thus, entrepreneurial efforts are essential for introducing innovations into the market. A vast array of theories and concepts has been employed to explore the entrepreneurship phenomenon (Westhead and Wright 2000). Some studies have focused on several units of analysis, theoretical perspectives, and methodologies (Low 2001). In addition to studying new firm development (Gartner 1988), exploration and exploitation of opportunities (Schumpeter 1934; Shane and Venkataraman 2000), and entrepreneurial behaviour of the existing firms (Iakovleva and Kickul 2011; Stevenson and Jarillo 1990), entrepreneurship research also examines institutional approaches (Busenitz et al. 2000; Scott 1995).

Institutional theory argues that institutions are embedded into regional and national context, which influence their development and overall performance (Scott 1995). This signals the importance of triple-helix university’s role and emphasizes the relevance of entrepreneurial efforts for introducing research-based innovations into the market. Academic spin-offs are one possible dimension that might eventually enhance entrepreneurial capacities in the RIS. The RIS framework is considered to be appropriate for studying innovation and knowledge flows in cross-border regions (Lundquist and Trippl 2009).

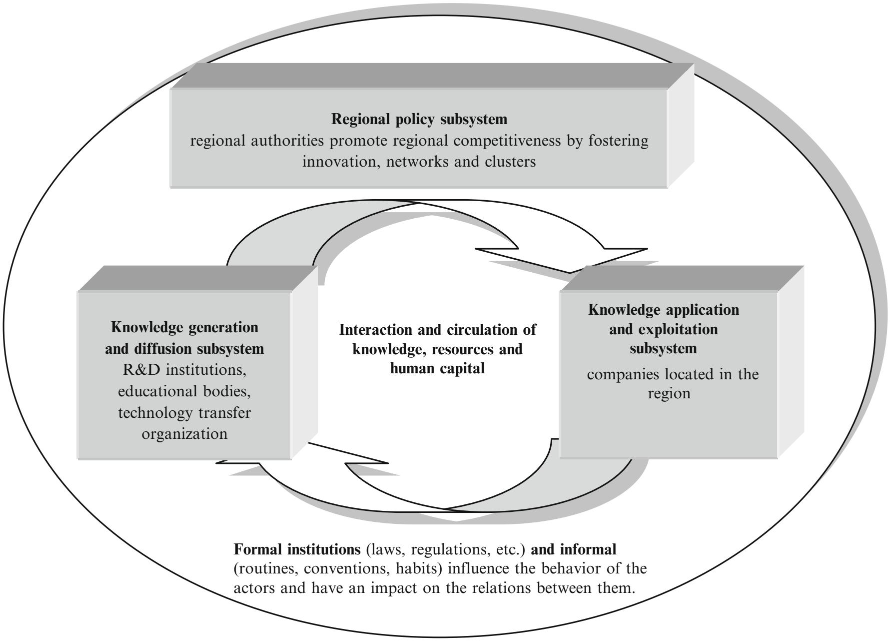

Fig. 5.1 Regional innovation system and its subsystems (*source*: adapted from Trippl 2006)

Guided by Trippl's (2006) research, as depicted in Figure 5.1 below, we suggest exploring triple-helix collaboration in the RIS through five major sub-systems. "Knowledge generation and diffusion subsystem" is associated with public research institutions, technology mediating organizations, educational bodies and workforce mediating organizations. "Knowledge application and exploitation subsystem" is connected with activities of the companies, clients, suppliers, competitors and industrial cooperation. "Regional policy subsystem" includes regional authorities, public authorities and development agencies. The efficiency of innovation development depends on local interactions between subsystems and the regional innovation system as a whole, which is influenced by socio-institutional factors, including laws, regulations, values, practices, routines and others. Since cleantech is the context of our study, all elements in the above mentioned system should be seen in relation to the development of this particular industry.

5.3 Methodology

In order to analyze the role of the triple-helix cooperation in the development of cleantech entrepreneurship in the Øresund and Moscow regions, we employed a combination of several methodological approaches. First, in order to grasp the scope of the situation, we acquired information from secondary sources comprising peer-reviewed articles, news reports, interviews and reports issued by reputable consulting firms. This allowed us to understand the overall situation, identify the existing elements of the innovation infrastructure and observe how the innovation ecosystem functions.

Second, in order to gain a deeper understanding of the phenomenon, we studied the interpretations through individuals with relevant experience (Shah and Corle 2006). Data for this study was collected according to qualitative methods (Denzin and Lincoln 1994; Silverman 2006). From February 2012 until February 2015, we conducted interviews and communicated with stakeholders from the Øresund and Moscow innovation systems. Using the case-study methodology of Yin (2003), we applied such methods as in-depth individual, semi-structured interviews. We interviewed representatives from universities and supporting infrastructure, entrepreneurs and politicians in order to understand their way of thinking and vision regarding the role of academia, triple helix collaboration and cleantech innovations. We conducted more than 30 semi-structured interviews based on the inductive approach where interviewees had much freedom in sharing their knowledge (Strauss 1987; Strauss and Corbin 1990). It is important to highlight the fact that a substantial number of the interviewed participants specifically requested us to avoid disclosing their personal information. However, this kind of communication allowed us to get the unique type of data, which would have been otherwise left out. Each interview did not exceed one and a half hours and was carefully transcribed for further in-depth analysis. All interviews were independently analyzed, respectively coded with regards to the research question and interpreted by the authors of this study.

We requested the selected interviewees to tell us about the role of their organizations in the Øresund and Moscow innovation systems as well as cleantech development. Furthermore, we attempted to acquire more detailed information regarding specific questions, for example, whether the representatives agreed or disagreed with our suggestions developed during the literature analysis stage. The interviewees also provided some insights based on their personal experiences and tacit knowledge. It is important to understand that new knowledge was not always immediately acquired as a result of received answers, but rather emerged during further analysis of the transcribed material due to the effort of both parties during each conversation. During discussions some interviewees paid more attention to describing the structure of interaction between organizations and functions of institutions, whereas others provided us with more information about specific functions and roles of their organizations in the system. Although new issues were identified during the interviews, not many overlaps and contradictions in the opinions of different interviewees were noticed. Furthermore, new information that was obtained from the interviewed representatives mostly complemented facts that were previously obtained at the literature review stage.

5.4 Findings

This section discusses the key findings identified during conducted interviews and presents a historical overview of innovations development process and the triple-helix role of academia in the two respective regions in relation to each of the five elements of our theoretical model—knowledge generation, knowledge application, regional policy as well as socio-institutional factors. Since it is often difficult to isolate each of these elements due to their complex inter-relationships, we chose a narrative way for describing RIS in the two regions.

(a) **The Øresund Region**

The 1990s were characterized by the beginning of the active cooperation between Swedish and Danish sides of Øresund in the field of innovation. Cooperation was stimulated by high density of talented individuals and institutions, relatively equal level of economic development, social and cultural similarities, and physical proximity of actors. Establishment of collaborative networks between regional administration, higher education institutions, research institutions and industry also helped to increase this cooperation. As of late, low-carbon and cleantech sectors are among the key priorities for development identified by Øresund. Moreover, according to several studies, Øresund is one of the leading regions for creation of entrepreneurial cleantech start-up companies and commercialization of clean technology innovations.

During the last decade entrepreneurial capacity has been increasing in the Øresund. There appears to be a trend towards an increasing number of research-based innovations that are related to social sciences instead of natural sciences. This trend significantly extends the magnitude and possibility for involving academia and students in promotion of research-based cleantech innovations. Such innovations are not always associated with new technological findings, but rather with their effective dissemination, which requires new solutions from social sciences including development of business strategies and policy measures. Low-carbon transition and cleantech development in Øresund could be related to new technological findings, their consequent practical implementation and successful commercialization of cleantech knowledge. Furthermore, application of current clean technologies could play an important role in these processes. It is also suggested that cleantech development could be based on the cooperation with other diverse industries. Moreover, it seems that social and sustainability innovations seem to have strong potential for growth in the Øresund RIS.

Some interviewees marked triple helix collaboration and cluster initiatives as fairly effective tools for the development of entrepreneurship and innovation in the region. Organizations such as Copenhagen Cleantech Cluster and the Sustainable Business Hub on Danish and Swedish sides respectively appear to be important actors for cleantech development since they both have proven to be effective in the dissemination of new and emerging technologies. They have encouraged local initiatives and promoted solutions on the international scale. Exchange of ideas, joint technology development and testing are seen as key factors for the development of cleantech entrepreneurship on both sides of the Øresund border. While it is expected that 12 billion euros of the total Danish cleantech export market value in 2010 will quadruple by 2015, already over half (51 %) of Swedish export consists of clean energy solutions (e.g., biofuels, solar, wind, hydro, sustainable buildings and energy efficiency technology).

The potential for the development of research-based innovations in the Øresund RIS is implemented through the collaboration between academia, industry and the regional authorities. Individual scientific talents are considered to be one of the most valuable assets for Øresund RIS. The triple helix model is utilized by the Medicon Valley Alliance (MVA),—the interregional cluster project which monitors the development of life-science innovations in the region. Initially, MVA was funded by the European Union as an Interreg initiative, but later on it became an independent project and is currently considered to be "the most successful project so far". At the same time, some of the interregional networking initiatives as well as the general level of awareness about these initiatives do not seem to be as advanced as they were before. Furthermore, It seems that the lack of a robust business tradition and understanding of the university-industry collaboration process could become a major barrier for the development of technology transfer solutions in Øresund. Therefore, it is important that technology transfer offices such as Lund University Innovation System at Lund University begin to proactively promote themselves among the various stakeholders in the region.

Measures that improve the entrepreneurial capacity of academia could also contribute towards the dissemination of cleantech innovations. The most prominent endeavour to increase entrepreneurial capital on the interregional level in Øresund was the Øresund Entrepreneurship Academy (active from 2006 to 2010). The Academy supported educators in the development of specialized courses and facilitated cooperation between academia and business organizations. The Academy became an important step for the development of entrepreneurial spirit in the region. Surprisingly, this project was abruptly halted in 2010. The reason for this was the apparent lack of interest from the Swedish side of the Øresund to continue the development of the entrepreneurial capacity and cooperation.

We have mentioned the anticipated trend in the increasing number of research-based innovations that are developed within the field of social sciences rather than in the field of natural sciences. Once again this allows for more extensive involvement of academia and students in development and further integration of research-based cleantech innovations. Although innovations within the field of social sciences may not be as technical as innovations in the scientific field, they include development of various strategies and policy measures which aid integration of technological innovations into life. However, interdisciplinary research centers that host natural and social scientists as well as industry business advisors and investors seem to have a much greater potential for the identification and development of new technologies compared to their mono-disciplinary counterparts. This happens primarily due to the fact that such centers provide a more "stimulating environment". At the same time, it is not always clear how to encourage interaction between academic researchers and business people in order to increase knowledge generation. Furthermore, it can be stated that sometimes students seem to have more entrepreneurial spirit than faculty since they are more willing to take risks. In Sweden, the SKJ Center for Entrepreneurship at Lund University has been promoting entrepreneurial education since 2011. The Center provides specialized courses on entrepreneurship and has also developed a new Masters program, which focuses on building new business ventures based on research ideas supplied by the University.

Low-carbon transition and cleantech development in Øresund could be related to new technological findings, their practical implementation and commercialization of cleantech knowledge. Furthermore, application of current clean technologies could play an important role in these processes. It is also suggested that cleantech development could be based on the cooperation with the existing non-cleantech industries. Moreover, it appears that social and sustainability innovations have strong potential for growth in Øresund RIS. Additionally, strategies for collaboration between cleantech startups and mature industries were provided. For instance, the Teknopol business advisory has two cleantech-related initiatives such as "Customer Financed Development" and "Verification and Innovation Purchasing". In the first case, an already existing company established a fund to help cleantech start-ups develop their technology to a point where they could possibly buy it. In the second case, Teknopol helped to translate the sustainability needs of large companies to a specific demand, which could then be met by the work of start-ups.

A degree of skepticism is present regarding the future of transnational collaboration due to unequal distribution of benefits between Danish and Swedish sides. An indirect evidence for that statement is that the interviewees were more interested in discussing innovation systems of their countries, rather than transnational innovation system of Øresund. Moreover, some of the initiatives had intraregional rather than interregional focus. Some of the most prominent integration achievements so far are related to the creation of favorable legislations for cross-border citizenship, employment opportunities as well as economic and social benefits that result from different and complimentary competences of the two sides.

(b) **The Moscow Region**

The Moscow region, which includes the city of Moscow and Moscow Oblast', an administration unit around the city, is considered to be the key economic and political area as well as one of the main innovation and entrepreneurship areas in Russia.

It could be suggested that there is significant potential for the development and implementation of cleantech innovations in Russia and particularly in the Moscow region, connected to the increase in energy efficiency, green building, waste management and some other cleantech sectors. For example, according to the World Bank research, Russia, including Moscow, is one of the world "leaders" according to its energy intensity of GDP. It presents a threat for the future development, but at the same time it could present opportunities for cleantech development. Recently some political incentives were introduced by the State which can potentially support cleantech development in Moscow and across Russia (for example, initiatives related to energy efficiency, renewables and waste management for example). Some interviewees, especially those who particularly had an entrepreneurial experience, considered it as a trend and saw the potential for this sector. At the same time, the macroeconomic and political perspective are not entirely optimistic, especially if the business-as-usual model of economic development associated with extraction and export of natural resources continues to persist in Russia. However, there are some potential niches for cleantech development, such as green building, which could eventually work in Russia.

There are some significant innovation-related projects, which have been started in the Moscow region during the past 10 years, such as the Skolkovo Innovation Center, an ambitious project launched by Dmitriy Medvedev while he was the President of the Russian Federation. Nevertheless, the innovation capacity of the region is mostly associated with the achievements of the Soviet period. There are a number of prominent higher education and research institutions, such as Moscow State University, Moscow State Technical University and Moscow Aviation Institute which are experienced in development and implementation of radical innovations. Although the importance of environmental and energy efficiency agendas has been rapidly increasing worldwide, the development of cleantech does not seem to be a priority neither for the State, nor for Moscow's regional development.

Before 1990, during the Soviet time, procurement needs of the Russian government's and state enterprises were the key incentive and an effective policy instrument for the development of innovations. After the collapse of the Soviet Union in 1990, the production and technological production chains were disintegrated, military procurement needs were significantly cut back, and the State's demand for innovations was minimized. Since the 2000s, the situation with the development of innovation and entrepreneurship slowly started to improve in general. Universities today play an important role in dissemination of new technologies. For example, Moscow State University (MSU) as one of the largest and most prominent universities in Russia, has an important role in promotion of the innovation activities across the Moscow region. There are several centers for education and research on innovation and entrepreneurship at MSU Department of Economics, in addition to the developing MA programs. There is also a science-park incubator which was launched approximately two years ago. Additionally, there are some innovation laboratories that drive research in the field of innovation and are also related to cleantech. Overall, MSU is considered to be a favourable place for developing innovations due to its support for the interdisciplinary research and education.

During the Soviet times, these universities were not necessarily a part of the regional innovation system, but rather had strong interconnections with different regions of the country, where fundamental innovations were implemented. Therefore, the innovation system associated with the regional academia was not limited to the geographical borders of the Moscow region. Despite the growing relevance of innovations for the current market of Russia, the state still does not prioritize cleatech development in its regional agendas.

As we mentioned before, the key driver for innovations development during the Soviet time was the needs of the government and state enterprises. Science, research and development (R&D), and innovations were part of the centralized planned economy, and thus main innovation areas of that time were heavy industry and military sectors. Together with domestic economy, economies of the third-world communist countries were also an important "market" for innovative knowledge-based production from Soviet Russia. Work at universities was very prestigious and profitable, while work at technical universities as an R&D professional was even more profitable. It was connected with the opportunities associated with participation in the promising R&D projects for the government. At the same time, entrepreneurship was an outlaw activity and there was no modern product-oriented "innovative thinking" in the Soviet time since there was no market economy. Additionally, the social and legal environment in the USSR was discouraging for any entrepreneurial intentions.

When the Soviet Union collapsed in the 1990s, the state did not prioritize innovations and, hence, no budget was allocated towards major development in any industry or other sectors. In academia, salary of the scientists and researchers was significantly reduced, which practically turned previously privileged scientists into the ordinary group of people with low income. Since the 2000s, the situation regarding the development of innovation and entrepreneurship slowly began to improve. According to the official documents and literature reviews, creation of university start-ups and involvement of students began to be considered as an important factor for connecting academic institutions with real economic sectors and labor market demands. The purpose of recent governmental initiatives is to develop cooperation between Russian higher educational institutions and industrial enterprises, develop scientific and educational activities in the Russian universities, promote higher education institutions' potential across enterprises in order to develop high-tech industry and innovation in the Russian economy.

For example, there is an initiative, which provides an opportunity for manufacturing companies to get a subsidy for funding projects related to the development of high-tech production in conjunction with universities. The key feature of this initiative is that it focuses on creating a cooperation network among scientific institutions from the educational sector and real sector enterprises. There is also a number of initiatives, which aim to transform leading universities into core elements of the innovation system, create the so-called innovation zones around them and develop various forms of networking within the framework of the innovative project implementation. In 2009, the Russian government issued a federal law that provided significant benefits for student entrepreneurship initiatives in order to promote such start-ups based on the universities' infrastructure.

However, despite the efforts to promote innovation development, it appears that current economic systems resist innovations and the existing state policy does not provide necessary support for the economic paradigm shift. In particular, the state's regulation of innovation development is considered to be "inconsistent and outdated". Moreover, it looks like that the government in some cases could be counterproductive with regards to innovation development, and could significantly skew current economic patterns in favour of particular individual interests. Additionally, it seems that there is a lot of "buzz" or brainwashing associated with innovations in Russia as well as "window dressing". Moreover, enterprises "could lie about their so-called 'innovations' in their reports". The key reason behind such patterns is the abundance of natural resources and the resource export-oriented economy of Russia. Therefore, until the government becomes an efficient player and starts generating real demand for innovations, it might be extremely difficult for universities to fully engage in triple-helix collaboration. There is also another task for the state, which should play an important role in developing interactions between researchers, managers and investors in order to, for example, avoid the opportunistic behaviour of the investors or to insure potential risks of the enterprises that develop innovations.

At the same time, it appears that there is no “magic” in promotion of entrepreneurship and innovations in Russian academia. It is also important to teach researchers how to acquire new skills and a general understanding of the market in order to develop market-oriented innovations. The remaining question is: how could we develop appropriate policies? On top of this, it looks like although there is enough state funding for the research, yet the problems of corruption and administrative barriers still remain. Another challenge is the existing mistrust between both sides of the innovation process—scientists and innovators.

5.5 Discussion

We adopted the approach of Trippl (2006) in order to analyze the triple helix role of academia in the development of cleantech in regional innovation systems in the Øresund and Moscow regions. The results of our research show that there are no strong interconnections between innovation and entrepreneurial activities in the Øresund and Moscow regions: in the case of Øresund there is a cross-border Danish-Swedish “semi-integrated” innovation system that consists of two RISs, while Moscow RIS could have stronger interconnections with the other regions of Russia.

Nevertheless, the regional innovation system as a research framework proved to be useful for our efforts in studying the role of triple-helix in the development of innovations and entrepreneurship within the regions. First, it allowed us to analyze the context of the innovation and entrepreneurship process. We studied the process—knowledge generation, dissemination, application and exploitation as well as learned about the regional policy subsystems, interactions of these subsystems and socio-institutional factors. Second, conducting interviews with different RIS stakeholders and analyzing their experiences helped us to obtain an understanding of the triple helix role of the academia, specifically regarding the examples of two universities—Lund University in Øresund and Moscow State University in Moscow Region. Finally, it helped us to study the development of cleantech as an innovation and entrepreneurship field.

The key differences between the Moscow and Øresund RISs are rooted in the history of the RISs development. During the Soviet time, the Moscow region did not develop market-oriented innovations, and entrepreneurship was illegal. The demand for innovation was regulated by the State’s policy and by the extent of export to the third-world countries. Nevertheless, some sectors such as military, space and heavy industry were quite effective in terms of extensive utilization of research-based innovations. The situation changed drastically during the economic crisis in 1990s, but since the 2000s the state interest and market demand for innovations and entrepreneurship were renewed. Integration of Danish and Swedish RISs on both sides of Øresund was connected to the intensity of higher education and research institutions, talents, presence of biotech companies as well as the national, regional, municipal and EU interest in promotion of the cross-border collaboration. Triple-helix collaboration and networking were the key instruments for development of interactions between administrations, academia and businesses on both sides.

Lack of entrepreneurial capacity and culture seems to be a common barrier for development of innovations in both the Øresund and Moscow regions. The reason for this is the traditional mindset combined with high level of social security in Denmark and Sweden on one side, and anticipated risks and administrative barriers in Moscow on the other side. Nevertheless, changes in academia towards stimulating entrepreneurial culture and developing innovation infrastructure could significantly contribute to major changes for the better. Some achievements were observed in the field during the last years, both in Moscow and Øresund. Promotion of entrepreneurship should be beneficial not only for the RISs, but also for the development of self-dependent, rather than state or big business-dependent types of professionals. This will also be beneficial for the economy and the society as a whole. It is imperative to increase interdisciplinary collaboration in universities in order to develop new innovations. At the same time, there is no need to force researchers to become innovators—since it could damage the capacity of academia.

It appears that a clear cleantech agenda could help stimulate triple-helix collaboration and the process of integration of the Danish and Swedish sides of the Øresund RIS. There is potential for having mutual benefits of regional branding as one entity and promotion and exporting of the complementary clean technologies. Contrary to the national authorities of Denmark and Sweden, Russian authorities currently seem to be less interested in promotion of cleantech. Nevertheless, some recently introduced political incentives have the potential to create the ground for development of cleantech. However, due to the role of private interest, administrative barriers and inefficiency of regulation, only certain sectors of cleantech could be developed and the process would not be based on the achievement of the academia. On the other hand, if the current trend of resource-based export-oriented economic development changes, cleantech should be placed at the forefront of the innovation development and the State could play the same role as it did during the Soviet times.

5.6 Conclusion

The objective of this study was to answer the following research question: "What is the role of triple-helix in the development of cleantech entrepreneurship?" by examining two different, yet comparable regions. We can conclude that for the most part the academia at present tends to serve as the provider of classical educational services, whereas its contribution to the direct knowledge transfer in the form of academic spin-offs is underdeveloped. Strictly speaking, while academia's role in knowledge generation is well established, it seems that it needs more support in its spillover efforts with respect to the knowledge application process. Regional policy subsystems formally proclaimed the need to foster innovations as their priority goal. In practice, however, we observed rather weak ties between academia and business, and socio-institutional factors such as laws and regulations that do not directly support the knowledge application processes. One of the general reasons for this disconnection, which could explain the obvious lack of cooperation is the cultural norms and values, where business and academia are often perceived as two parallel rather than overlapping worlds.

In conclusion, our findings confirm that cooperation and circulation of knowledge, resources and human capital across the regional policy subsystem, knowledge generation and diffusion subsystem, and knowledge application and exploitation subsystem can generate new combinations of knowledge and resources that can advance innovation theory and practice, especially at the regional level.

5.7 Further Research

To conclude, we would like to point out that our research was carried out with certain limitations. Based on a limited number of selected informers, we have only managed to obtain a preliminary overview of the opportunities and challenges on the way to academia development in the cleantech industry. Our findings indicate that the smooth interaction process between practical and academic worlds remain the key challenge on the way to promoting innovation in the RIS. In our opinion, future research should address the dynamics of such interrelations in greater depth. The issues of human mobility as well as issues of shared network and acting space where academics can meet real world challenges and present their scientific findings to the business community deserve more attention.

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Chapter 6
Key Factors on Green Product Development: Influence of Multiple Elements

Jorge Julião, Marcelo Gaspar, and Benny Tjahjono

Abstract Green product (GP) development has become a key strategic consideration for many worldwide organisations, mainly due to environmental regulations and public awareness of environmentally conscious practices. In particular, companies are devoting more attention to products which reflect the need for environmental preservation, as well as allow them to maintain their market share and competitive advantage (sustainable economy). However, the market shares of many GPs have not increased in correspondence with the rising environmental awareness. Therefore, it is relevant to identify and discuss the role of the key factors that influence GP development.

The purpose of this chapter is to identify the main actors (consumers, companies, universities and governments) that influence GP development and discuss their implications. As GPs are considered to be a value driver, it is worth emphasising that the pursuit for high environmental performance of sustainable products can positively contribute to an organisation's competitiveness and customer expectations.

A comprehensive literature review analysing the state-of-the-art concerned with GP development, along with results of surveys and cases, sustains the qualitative discussion on the key factors that influence the development of products, which have a reduced environmental impact during their whole life-cycle. The chapter concludes by presenting a framework derived from a Multiple Helix approach on GP development that identifies the key factors associated to the main actors, as well

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as their interrelationships in this ecosystem. The body of knowledge that has been created here is meant to support mainly students and practitioners, but also new researchers, who are addressing the problematic issues of GP development.

6.1 Introduction

The aim of this chapter is to identify some of the main actors, such as consumers, companies, universities and governments that influence GP development and discuss their implications.

Although there is generally no agreed-upon definition, a ‘green product’ can be defined as a product, or service, which is developed to reduce environmental impact over the entire product life-cycle (Albino et al. 2009). These products strive to protect or to enhance the natural environment by conserving energy and/or resources and reducing or eliminating the use of toxic agents, pollution, and waste (Dangelico and Pontrandolfo 2010; Tsai 2012), using environmental-friendly materials, with end-of-life strategies (Joshi et al. 2006), among others.

The increasing purchasing power of consumers, particularly in economically developed countries, has fostered over-consumption (Mont et al. 2014) and natural resources exploitation leading to environmental deterioration. In general, almost all consumed products cause environmental impact in at least one of the life-cycle stages. For example, the impact of furniture may be primarily on forests, whereas the main impact of home appliances typically occurs during usage and at disposal. In order for products to be eco-friendly, the environmental impacts of the whole product life-cycle have to be taken into consideration. One efficient way of reducing the environmental impact of products is to consider the sustainability factors when products are being developed (Albino et al. 2009).

Environmental protection and preservation have become a widely accepted, mainstream issue for consumers. This increasing consumer awareness of environmentally conscious practices (Yung et al. 2011) is motivating more companies to develop GPs (Chen 2011). On the one hand companies aim to create products that satisfy customer needs and wishes. On the other hand, consumers are more concerned about the environment (Ginsberg and Bloom 2004), paying more attention to GPs (Chen and Chang 2012) and are more willing to pay a premium price for GPs (Bhat 1993; Makower 2009). Moreover, the environmental awareness may be a consequence of regulatory pressures to protect the environment (Wang et al. 2015), e.g. the European Council’s (2009) Directive, which requires companies to comply with eco-design principles in order to sell their products to the European Union.

Companies are challenged by social demand and government policies to develop greener and more sustainable products. As a result, a growing number of companies are embracing the concept of environmental sustainability into their business and environmental strategies (Aragón-Correa and Sharma 2003; Dyllick and Hockerts 2002). Most of them need to adapt their practices to the new technologies in order to minimise environmental impact at each life-cycle stage. Universities have an active role integrating existing theories to the greening process. However, in practice, it appears that incorporating this into industrial products and processes still remains a challenging task (Karlsson and Luttropp 2006; Verhulst and Boks 2012; Brones and Monteiro de Carvalho 2014).

Despite many companies investing in green production and marketing (Gleim et al. 2013), consumers do not purchase GPs as regularly as expected (Polonsky 2011). Moreover, although several consumer surveys indicate that most consumers are environmentally concerned and are inclined towards purchasing GPs, they do not buy GPs with overwhelming preference (Kilbourne and Pickett 2008; Chen 2008). Consumer attitudes towards the environment do not always materialise in their purchasing behaviour. Therefore, notwithstanding the rising environmental awareness around the globe the market shares of many GPs have not increased in correspondence. It is estimated that the market share for GPs is less than 4 % (Gleim et al. 2013). This suggests that GPs in the marketplace are not fulfilling consumer expectations. Accordingly, the aim of this chapter is to discuss some of the main factors that influence the development of GPs that are aligned with both environment and market requirements.

6.2 Consumers

Commercial success of GPs in the market place is crucial in helping to drive companies and society towards environmental sustainability (Hall and Clark 2003). Accordingly, GP development has become a key strategic consideration for many companies due to regulatory requirements and the consumer awareness of environmental protection. The aim of this section is to discuss factors, or drivers, considered by consumers when purchasing GPs, so they can be integrated into GP development in order to assure consumer preference and meet their expectations.

6.2.1 Perceptions: Quality and Price

Developing a product which excels in environmental terms while remaining economically and technically competitive, is a significant challenge (Pujari 2006), as in most instances it implies making trade-offs. For example, although electric cars produce lower levels of pollution, they do so at the expense of speed and duration (De Neufville et al. 1996). The Mintel report (Mintel 2009) shows that although the demand for GPs shows signs of increasing, only a few consumers considered sustainability factors in their last major purchase. This suggests that price and quality are more relevant when carrying out purchases than green factors. Moreover, consumers tend to be price and quality sensitive when it comes to buying GPs (Mandese 1991). The results from Khosla and Taghian (2005) indicate that consumers are more strongly resistant to lower quality than higher prices regarding GPs in comparison to other alternative non-GPs.

This suggests that GPs need to demonstrate at least a comparable quality to the non-GPs and if quality is improved consumers may be willing to pay a premium price. However, higher prices must be related to the benefits that consumers will gain when using or consuming these products (Tomasin et al. 2013), since the perceived quality of GPs, directly affects the intent to purchase (Tseng and Hung 2013). Some researchers identified that the price of GPs and other costs associated with their use influence purchasing decisions (Gleim et al. 2013) and consumers will not pay higher prices for these products (e.g. Wasik 1992; Graviria 1995). Conversely, other researchers argue that consumers are willing to pay more for GPs (e.g. Laroche et al. 2001; Cherian and Jacob 2012). These results suggest that non-green consumers are unwilling to pay a premium price for GPs offering the same quality as traditional products, because price sensitivity is related to the perception of value added by GPs and this value is often only evident in the long-term (Drozdenko et al. 2011).

Furthermore, this value is, in general, miscommunicated and non-green consumers are typically reluctant to search for information (Gleim et al. 2013; Zhao et al. 2014) and view GPs as less effective than non-GPs (Lin and Chang 2012). Concerning quality, both non- and green consumers expect the quality of GPs to be in no way inferior to traditional products and are unwilling to trade off product qualities for a product's green attributes (Lin et al. 2013).

Although consumers in general show some scepticism regarding the quality of GPs, green consumers seem to be satisfied with their quality (Ritter et al. 2014). Regarding the price, nevertheless it is one of the most important buying criteria (Roberts 1996), green consumers are less sensitive to price (Ritter et al. 2014) and are willing to pay a premium price if the associated value is perceived. Thus, the way in which the value of GPs is communicated to consumers is also an important factor to be considered.

6.2.2 Behaviour: Information and Labelling

The market availability and experience of GPs is less than for traditional products, which makes current knowledge about GPs limited (Spangenberg et al. 2010). This increases consumer doubts regarding their specifications, green claims and added value. Therefore, it is imperative to understand the impact that information and labelling has on GP sales and consumer expectations regarding product information.

The information and labelling is directly correlated with GP sales. According to Tomasin et al. (2013) technical specifications are essential to increase the sales of GPs. Moreover, the Mintel report (Mintel 2009) shows that the lack of adequate information and labelling may be limiting the ability of consumers to purchase GPs. It is also understood that product value is one of the most important buying criteria for GPs (Roberts 1996) and that GP consumers tend to analyse prices according to their perception of value added (Drozdenko et al. 2011), therefore, product information needs to be efficiently transmitted to consumers. Nevertheless, although information about the environmental advantages of GPs and the gains associated with well-being and health is recognised as encouraging sales, consumers have little knowledge about the subject (Cherian and Jacob 2012).

Regarding product information, environmental labelling is an effective way of communicating to customers the specific benefits and characteristics of the product and the claim, which can be displayed by using symbols or messages (D'Souza et al. 2006). Consumers prefer more detailed and specific information to support GP claims (Manrai et al. 1997) and technical specifications have to be better than those of the non-GPs to generate new sales (Tomasin et al. 2013). Moreover, consumers tend to value GPs with certificated information more highly, like a seal of quality, since they are willing to pay more for these products (Cason and Gangadharan 2002). Less stringent quality signals, like labels that include a simple logo or graphic are seen as little more than a marketing promotion (Teisl et al. 2001). This may be explained by the increased amount of trust consumers tend to have in a government-sourced condition than in a corporate-sourced condition (Atkinson and Rosenthal 2014). Moreover, more detailed information and substantial claims may lead to higher levels of consumer trust and more favourable attitudes towards the product and label source (Atkinson and Rosenthal 2014), increasing the consumer purchasing intent (Chaudhuri and Holbrook 2001).

Although GP consumers seek information about environmental effects and information (Spangenberg et al. 2010), non-green consumers are usually not interested in receiving this information (Cherian and Jacob 2012). This suggests that GP labelling should be designed focusing on green consumers. As the non-green consumers represent a significant market share that cannot be discarded by companies, an approach to this market based on marketing would be more effective rather than on labelling. The role of green marketing is to popularise GPs and educate consumers, emphasising what consumers can expect from GPs in both the short- and long-term (Polonsky 2011) and overcoming the lack of awareness and trust vis-à-vis GPs (Bonini and Oppenheim 2008).

6.3 Companies

There is no doubt that companies are currently increasing their efforts to develop greener products through the integration of environmental sustainability issues into their business strategy. As a consequence, sustainability is currently perceived as a cardinal driver of innovation by companies (Santolaria et al. 2011). Although, there is still little knowledge on why and how companies integrate environmental sustainability into new product development (Dangelico and Pujari 2010), research shows that companies develop GPs to satisfy consumer demand (Horbach 2008; Horte and Halila 2008), address pressure from interest groups (Wagner 2007), and changes in regulation (Porter and van der Linde 1995a; Dangelico and Pujari 2010). The aim of this section is to discuss the main aspects related to company GP development issues and to discuss the main challenges and opportunities identified in this endeavour.

6.3.1 Products: Challenges and Opportunities in Green Product Development

Companies are profit oriented organisations that obtain their revenue from the sales of products, which can be tangible goods, services or a combination of both. Considering the market's demand to constantly develop new products, the integration of environmentally sustainable solutions in this process is considered a key challenge in the development of greener products. It has also been confirmed by different researchers (Sharma and Vredenburg 1998; Sarkis 2003; Doran and Ryan 2014) that GPs can improve a company's competitiveness. However, Barsoumian et al. (2011) dispute that in many companies economic drivers, such as cost reduction, may lead the decision to eco-innovate, and Saxena and Khandelwal (2012) argue that an environmentally sustainable strategy is needed if a company wants to gain a competitive advantage. Nonetheless, environmental sustainability can be perceived by companies either as limiting their modus operandi or as an opportunity to reduce their operational costs and environmental impact. To reach these goals, most companies have to adapt their practices, taking advantage of environmental regulations and standards, internal and external pressures, and technological advancement, focusing on green innovation. Chen et al. (2006) have conducted a study showing that investment in GP innovation by means of environmental product-development practices leads to improved competitive advantage, based on positive results in indicators such as product cost, quality and flexibility. Wong (2012), Lin et al. (2013) and Driessen et al. (2013) point in the same direction, confirming that innovation in GPs improves competitive advantages such as improved product quality and company reputation. Zeng et al. (2011) and Jabbour et al. (2015) confirm that environmental performance and economic performance are positively correlated, whilst Ellram et al. (2008) and Zeng et al. (2010) show that it is possible to reach environmental sustainability goals while meeting organisational profitability targets and excellence in new product performance. This allows one to conclude that although a greener production strategy may present different challenges and opportunities to companies, it can have an overall positive impact on their business performance.

6.3.2 Impact: Sustainability and Eco-labelling of Green and Non-green Products

Almost all, green and non-green products, have significant environmental impact in at least one of their entire life-cycle stages. As for GPs, the aim is to reduce their impact on the environment (Joshi et al. 2006), but the truth is that they can never be completely avoided. To measure and evaluate this impact, companies can use a large variety of environmental assessment methods and sustainability assessment tools. Life Cycle Assessment (LCA) has been increasingly used to identify, quantify, check, and evaluate information related to the environmental impact of products. ISO 14040 (2006) and ISO 14044 (2006) standards define the principles, requirements and guidelines of this tool, which forms part of the ISO 14000 Environmental Management Standards. Even though) LCA may be considered a somewhat complex tool, it allows inputs of water, energy, and raw materials to be quantified in the different life-cycle stages, in turn allowing the released substances and impact to the environment to be quantified, in relation to air, land, and water. Only by assessing this type of quantitative environmental data can a company develop solutions to lower their impact, and consequently produce environmentally friendlier products. Porter and van der Linde (1995a) had already stated that reducing environmental impact at lower costs could be perceived as an opportunity by companies, mainly by redesigning products, processes, and/or operation methods. Although GP innovation is becoming mainstream among companies and ecological awareness policies may be related to customer retention (Sisodia et al. 2007), there is still a lack of knowledge about what constitutes a green or sustainable product concerning the customer (Baumann et al. 2002; Berchicci and Bodewes 2005). Due to the difficulty of fully communicating the environmental advantages of their greener products, companies are facing increasing challenges to successfully promote these advantages in order to attract, satisfy, and retain customers. Associated to this lack of awareness of the environmental benefits of GPs, often customers are not willing to pay a premium price for these differentiating attributes (Dangelico and Pontrandolfo 2010). Even if customer awareness is raised by means of eco-labelling, which allows the environmental benefits of the products to be communicated to the customers, a third party certification is still needed to create credibility through a scientific and systematic assessment of the product's environmental impact at each life-cycle stage.

6.4 Universities

In recent years, academic research on environmental sustainability has grown in terms of interest and results, allowing existing theoretical models, which are linked, to address questions raised within the environmental field. Alongside their fundamental research, universities have also aided companies in the development of GP and process solutions, achieving a better alignment between what is commercially feasible and what is environmentally sound. The aim of this section is to discuss the main aspects related to the research and development undertaken at universities in relation to environmental sustainability issues, as well as their role in conveying overall information and knowledge concerning public awareness of environmental protection.

6.4.1 Research: Information and Knowledge on Environmental Sustainability

Environmental consciousness refers to the ability to reshape habits addressing the minimisation of environmental effects (Schlegelmilch et al. 1996) and is both triggered and stimulated by state-of-the-art academic research. With this aim, environmental sustainability research benefits universities, allowing, amongst others, the university's social function to be fulfilled; acquisition of practical knowledge regarding existing problems; incorporation of new knowledge into teaching and research practices; additional financial resources; prestige for the researcher; and publicity for the university (Natário et al. 2012). The role of creating knowledge and information by academia for all relevant actors, e.g. government, industry and society, allows their expectations and their decision-making process regarding environmental sustainability issues to be supported. As a consequence, the more information available regarding the benefits to the environment through the development and use of GPs, the more this may result in an increase in their consumption (Ritter et al. 2014), as the size of green markets is increasing and is likely to expand in the future (Dangelico and Pujari 2010). It has been suggested by Cherian and Jacob (2012) and Ritter et al. (2014) that consumers generally have limited knowledge of the advantages of GPs for the environment, health, and society. Even though environmental labelling on products is reported to be an effective way of communicating specific benefits and qualities of GPs to customers (Cason and Gangadharan 2002; D'Souza et al. 2006; Biswas and Roy 2015), it is shown that trust issues regarding the source of such information may affect consumer behavioural outcomes (Manrai et al. 1997; Atkinson and Rosenthal 2014). In this sense, universities are needed, as independent third parties, to evaluate and certify company claims related to the environmental benefits of GPs, providing credibility to the customers.

6.4.2 Development: Role of Academia in the Development of Greener Products

In recent years, there has been an upsurge in the reporting of R&D in the area of environmental sustainability and green innovation. Within this field, academia has contributed actively towards a better understanding of the development of GPs (Foster and Green 2002; Berchicci and Bodewes 2005; Tseng and Hung 2013). As a result, they offer normative guidelines, manuals, tools and advice to engineers and managers to help them integrate the state-of-the-art knowledge into their GP development processes (Berchicci and Bodewes 2005; Pujari 2006). The aim of these tools is to identify the environmental and cost-related implications of alternative materials or process decisions, helping companies to develop greener products (Berchicci and Bodewes 2005). Although the theory and methods are available, in practice it appears that applying eco-design research, whether academic or applied, to the final product is not an easy task, possibly due to the lack of a holistic approach to the implementation process, from a theoretical and empirical point of view (Brones and Monteiro de Carvalho 2014). The challenge facing industry, practitioners and scholars supported by policy agendas has been on how to incorporate environmental issues into product development. In this sense, research shows the existence of a gap between the proponents of sustainability and those who develop the GPs (Pujari 2006; Brones and Monteiro de Carvalho 2014). To this end, an even greater effort has to be made amongst academia and industry to integrate and link existing theories to the greening process.

6.5 Governments

This section discusses the role that environmental regulations (ER) play in stimulating GP development, and argues that these regulations are critical in boosting GP development (Wagner and Llerena 2011; Kesidou and Demirel 2012).

6.5.1 Impact of Regulation

Many countries and economies are taking measures to increase sustainability at national and international level, through the creation of declarations and regulations for environmental protection (e.g. Montreal Protocol, Kyoto Protocol, European Community directives on the restriction of the use of certain hazardous substances and on waste electronics and electrical equipment), which have become an important way of encouraging the development of GPs. Nevertheless, there is some reluctance to accept these regulations to protect the environment by many companies, and consequently they are overlooked (Heyes 2000) because they are often viewed as a cost-increasing factor and perceived as a constraint.

However, ER do not represent only constraints for companies. In fact, they can become an opportunity for new business creation, trigger innovation and GP development (Wagner and Llerena 2011), and contribute to an increase in competiveness (Porter and van der Linde 1995b). ER can even generate 'win-win' opportunities with environmental gains and an increase in productivity (Porter and van der Linde 1995b; Kemp et al. 2001). Furthermore, some companies view compliance with ER as a means for risk minimisation, revenue, and image protection (Dangelico and Pontrandolfo 2010).

The use of plastic bags is an example on how ER may prompt the creation of new business and new GPs. When the use of plastic bags started to be restricted, in some economies, new companies producing bags with a low environmental impact were established. Moreover, both the Dutch flower industry and Denmark's energy transition are two success cases of the ER application. Although some argue that they are the exception rather than the rule, they are inspiring examples. Pressured by strict regulation on the release of chemicals, the Dutch flower industry created an innovative eco-flower production process (greenhouses) that not only allowed a reduction in the need for fertilizers, pesticides and water, but also led to an improvement in the product quality, a reduction in production costs, and an increase in productivity and enhanced business competitiveness. Denmark successfully adopted an energy sustainability model that allowed the transition from a fossil fuel-dependent society to an environmentally sustainable one, achieving high levels of welfare and economic growth.

As claimed in some literature, ER are a direct driver of green innovation (e.g. Johnstone et al. 2010; Wagner and Llerena 2011), and they have been repeatedly claimed as the most important stimulus for innovation (of GPs) (Green 2005). Therefore, increasing attention has been given to the role of regulation in enhancing investment in GPs (Brunnermeier and Cohen 2003), and is very much under debate (Qi et al. 2007). However, there are contrary views that suggest the costs induced by complying with strict environmental regulations compromise competitiveness (Palmer et al. 1995).

6.5.2 Role of Incentives

Results from empirical research at firm-level suggest that more stringent ER boost green innovation (Frondel et al. 2008), positively contributing to GP development. Regulations can force companies to invest in environmental research and development, which may lead to an increase in efficiency, for example by reducing the cost of complying with these regulations (Porter and van der Linde 1995b), by reducing production costs and/or entering into expanding markets for GPs. Moreover, the efficient use of resources imposed by ER, can greatly reduce a company's operation costs (European Commission 2013).

Although it is generally assumed that the severity of the ER contributes to higher levels of green innovation (Brunnermeier and Cohen 2003), they may not affect the investment of all companies in green innovation uniformly, and their effect on companies can differ considerably (Portney 2008). Some researchers suggest that only the least and most innovative companies are highly driven by these regulations (Kesidou and Demirel 2012). The less innovative companies tend to follow a more reactive strategy and adopt ER to increase efficiency and reduce the production costs of complying with the regulations. On the other hand, highly innovative companies tend to be proactive in order to be ahead of their peers, and many are already complying with ER. For these companies the regulations may increase investment in green innovation for strategic reasons, i.e. to gain market advantage as the first-mover (Grubb and Ulph 2002; Kesidou and Demirel 2012). This suggests that ER may have a stronger impact on GP development at highly innovative companies, and where pressure to innovate is less pronounced (Leitner et al. 2010).

Moreover, a central problem with ER is to know how stringent regulation must become to trigger innovation and how mild regulation has to be to avoid resistance and opposition (Leitner et al. 2010). The answer to this dilemma is complex and not linear, since it depends on contextual factors, like the type of company. In general, large companies have more resources to fund innovation, whilst smaller companies have the advantages of flexibility and adaptability that make innovation by design more agile. It is also believed that by reducing the severity of regulations less innovation is stimulated. On the other hand, regulatory stringency, where regulation is very prescriptive, may reduce the flexibility of small companies, leaving the field of innovation for larger companies (Leitner et al. 2010). These arguments raise the question as to whether ER should be tailored according to the company size.

Governments have been using different regulatory instruments (policy instruments) to encourage the adoption of ER towards GPs (green innovation). While it seems to be unclear as to which regulatory instruments dominate other instruments, the instruments which provide economic incentives (e.g. benefits or negative taxes) normally perform better than command and control regulation (Requate 2005). The benefits have different forms, and purposes other than the incentive of GP development, for example, the promotion of renewable energy sources and the reduction of material use and waste. Moreover, benefits can increase green product sales (Olsson and Gärling 2008) and promote company investment in GP development (Aalbers et al. 2009).

Environmental regulations do not lead inevitably to GPs and improvement of competitiveness. However, it is pivotal that governments introduce correctly designed ER, which have a critical impact in encouraging the adoption, creation and diffusion of green innovation and GP development. Nevertheless, the complexity of both regulations and innovation processes makes the relationship between them complex, and it is not yet fully understood. Moreover, the impact of ER on GP development will depend on the design instruments, stringency of the regulations and the context in which they are applied, particularly the type of company. Environmental innovation in general, and GPs in particular, will certainly contribute to the sustainability of societies. For this to occur, there is a need for systematically improved environmental regulation, as well as environmentally motivated innovation policy (Leitner et al. 2010).

6.6 Conclusions

In a Multiple Helix system, interactions amongst the different actors evolve from the traditional university–industry–government relations to a wider approach, where society, with its different roles and contributions, is considered (Carayannis and Campbell 2009; Carayannis et al. 2012, 2015). In the current GPs development model, societal aspects are discussed from a consumer's point of view, where their needs, expectations and attitudes are addressed. The interrelations amongst all actors in a Multiple Helix approach on GP development is synthesized in the conceptual framework presented in Figure 6.1 This interaction model was derived in order to identify and schematically display the main interrelations, and consequent multi-level flows, amongst all actors of this ecosystem.

In the context of the developed framework (Fig. 6.1), it has been shown that the main outputs of governments addressing GP development are both regulations and incentives empowering environmental sustainability. Governments promote green innovation at different levels, supporting academic research, defining policies and incentives at an industrial level and also directly to the market, benefiting GP consumption towards non-GP products. On the other hand, the government decision-making process is supported by the know-how provided by the universities and is driven by the market behaviour. This behaviour is translated by market research data and the resulting taxes that companies and consumers pay related to products and processes. Governments can increase, or decrease, tax rates regarding environmental sustainability. Considering that company-consumer interrelations are mainly market driven, it has also been shown that environmental thinking can stimulate green consumption. To this end, universities perform a major role, not only with the dissemination of environmental awareness information and applied knowledge

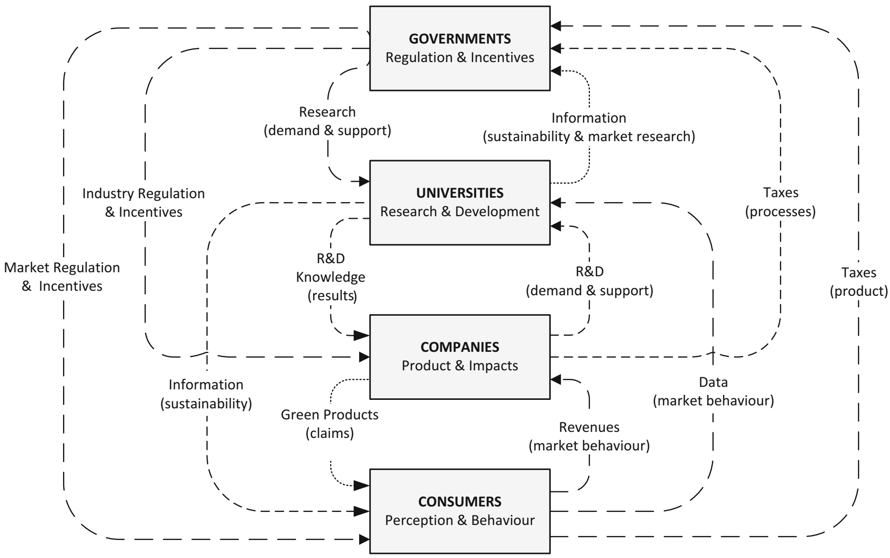

Fig. 6.1 Multiple helix conceptual framework on GP development

resulting from their research, but also as a credible third party concerning eco-labelling evaluation and certification. The aim of the developed framework (Fig. 6.1) is to identify the major guidelines and key factors regarding an improved understanding and characterisation of the main actors of a Multiple Helix approach to the GP development ecosystem. The resulting body of knowledge is designed to support mainly students and practitioners, but also new researchers, who want to address the problematic issues of GP development.

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Chapter 7
Sustainability, Lean and Eco-Efficiency Symbioses

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Abstract A literature review was conducted aiming at investigating the use of Sustainability, Lean, Green and eco-efficiency concepts, as well as meaningful combinations of those, on the field of Production and Operations Management. The study reports on the scientific papers published in all major journals in the field over the period 2001–2015. A set of 83 papers from 40 journals were selected for further analyzes, aiming at uncovering the existing level of awareness and use of the synergic and symbiotic relationship between Lean Manufacturing and Green Production. The findings show that a modest share of papers, about 30 %, explicitly recognize the Lean-Green joint approach. The same study testifies a clear growth pattern, which is patently reinforced in the last two and a half years, on the number of papers that behold a combined approach towards more efficient and cleaner production activities. The research has highlighted that the Lean-Green link does, in fact, exist and is gaining momentum, but requires further reinforcements from the scientific community, as well as from the companies, to deliver excelled and environmentally sound production systems.

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7.1 Introduction

Production is a key economic activity which provides the products demanded by the marketplace in order to fulfill the needs of a growing consumer society. Many decades of intensive industrial activity has not only exploited the planets' resources, e.g. with massive operations around the globe for extraction of raw materials and fuels, but also resulted in undesirable emissions that polluted the air, soil, and water. The general behavior of consumers seem to exhibit no limits, which, on the long run, severely impact the ecosystems and threatens the species survival capability. The planets' natural self-regulating mechanisms might change accordingly, to cope with the scale of the impact. This is envisioned to occur in shorter time frames than ever, which, per se, might endanger human life, as a species. The climate change phenomenon is one such mega threat that, given the magnitude of risk, worth consider seriously.

A genuine and honest approach to mitigate such challenges is that of considering environment and social responsibility, on all relevant aspects of activity, not only economic ones. This should be accomplished by people, when buying, using and disposing all stuff, and particularly by companies, when designing the products, sourcing the raw materials, and on carrying out the production activities that aggregate value to the product. Some companies are trying to achieve just that, by developing proactive attitudes and strategies towards more sustainable operations, i.e. through cleaner production and compensation mechanisms, which offer a more balanced way to the use of nature, where eventual losses are, at least partially, counterweighted with positive environmental rewards. To achieve a balance, companies have been adopting some strategies and organizational methodologies that promote ideas of "creating more with less", as encouraged in the concept of eco-efficiency, and of "doing more with less", as endorsed by Lean Production. The synergies among those strategies are plenty and unequivocal, which has resulted in an approach known as Lean-Green.

However, it remains the case, that the breadth of awareness of the Lean-Green link requires further study, analysis and clarification, within the field of Production and Operations Management. For this purpose a study was conducted, whose main research question was: *"Does research on Sustainability, in the field of Production and Operations Management, exhibits a link to that of Lean and/or Eco-efficiency concepts?"*

The next sections attempt to bring some light on the underlying research question. After this brief introduction, five more sections follow. A brief background on lean production, sustainability, eco-efficiency and lean-green is presented on Sect. 7.2. Section 7.3 explains the research methodology while the fourth one presents the data analysis and synthesis. The main findings are discussed in the fifth section. Finally, in the last section, some conclusions and future research lines are presented.

7.2 Background

This chapter intends to provide some background on the concepts and definitions of Sustainability, Lean Production, Eco-efficiency and Lean-green.

7.2.1 *Sustainability*

Sustainability is the key concept underlying the sustainable development because it is the framework of this development mode. The idea of sustainability came, in part, of human awareness of finitude of resources provided by nature (mineral, vegetable and animal) over time. So originated in Biological Sciences renewable resources, especially those who may be terminated by the uncontrolled exploitation, then, can be understood as the quality of what is sustainable, meaning *ab aeterno* maintenance and conservation of natural resources, i.e., it means, making use of natural resources without destroying them, without exceeding its resilience, without excluding the possibility of their use by future generations. Colombo (2004), based on the view of Sachs (1986) understand that sustainability is the idea of minimizing the irreversible changes, leaving open the possibilities for the present and the future, in a very wide time scale. Is the awareness that every living being is not alone, that all are part of a network, and each node of the network destroyed destroys a little of each of the other nodes, among which we are one and the quality of life of all depends on the life of that whole.

According to Costanza "Sustainability is a relationship between dynamic human economic systems and larger dynamic, but normally slower-changing ecological systems, in which (1) human life can continue indefinitely, (2) human individuals can flourish, and (3) human cultures can develop; but in which effects of human activities remain within bounds, so as not to destroy the diversity, complexity, and function of the ecological life support system." (Costanza 1991, pp. 8–9).

Although the perceived need to stay within limits of natures' recovery capacity is rather important, it is necessary to widen the spectrum of what needs to be done and preserved, e.g. cultural diversity. The idea of sustainability, then, is not restricted to nature, it also involves other dimensions. Various dimensions of sustainability can be found in a number of distinct authors (Diegues 1992; Sachs 1993; Munasinghe 1993; Pelizzoli 1999; Ultramari 2001; Colombo 2004; Pappas 2012) such as: social, economic or financial; ecological or environmental; spatial or territorial or geographical; cultural; policy; technique; institutional; demographic; planetary. Some authors present some of these combined dimensions, such as socio-cultural (Munasinghe 1993) or spatial-political and political-temporal (Sachs 1998). In the business/industrial field becomes special attention to the so-called "triple bottom line" (3BL), namely the economic, environmental and social sustainability.

7.2.2 Lean Production

Lean production is an organizational methodology that has been spreading across all major sectors of economic activity. This methodology has roots on the Toyota Motor Company, which, after the Second World War, devised and applied a new production approach named Toyota Production System (Monden 1983; Ohno 1988). That particular period of time, was a period of strong financial restrain and resource scarcity in Japan, which pushed forward some innovative thinking, for providing new solutions, to return more value in a more effective way. Toyota Motor Company looked for a solution that performed what mass production did best, i.e. spending the minimum resources to make things, under a stringent economy. The new paradigm was coined "Lean Production" by the MIT researchers, and became internationally known after the publication of a best-seller book by Womack et al. (1990).

Toyota engineers designed a solution where they spend less resources, less human effort, less space and fewer inventories by eliminating all wastes. Wastes are all activities that do not add value to the products and were classified by Ohno (1988) in seven categories: (1) overproduction; (2) over processing; (3) transports; (4) defects; (5) motion; (6) inventory and (7) waiting. Additionally, untapped human potential is considered the eighth waste (Liker 2004). To systematically eliminate these wastes, Womack and Jones (1996) designed the Lean principles: (1) Value; (2) Value Stream; (3) Flow; (4) Pull production and (5) Pursuit of Perfection.

Pursuit of perfection means being constantly looking for continuous improvement (*kaizen*) and the ones capable of doing this are people. So, the most important asset in a company is people involvement and creativity, which is promoted in a real Lean culture environment, since people emerge as thinkers in one such environment (Alves et al. 2012). The committee for Foundational Best Practices for Making Value for America (Donofrio and Whitefoot 2015, p. 5), recommended: *"Manufacturers should implement principles and practices such as Lean Manufacturing that enable employees to improve productivity and achieve continuous improvement."* According to this committee, companies and communities must take action to upgrade America's ability to "make value" to prosper in the twenty-first century, and therefore make a paradigm shift from the traditional mass to the lean production.

7.2.3 Eco-Efficiency

The eco-efficiency concept was introduced in the early years of 1990s, by Stephan Schmidheiny and the Business Council for Sustainable Development (BCSD). The concept was envisioned to sum-up the intent of fostering sustainable development by delivering truly green products/services that genuinely contributed to human well-being. The Business Council for Sustainable Development defines eco-efficiency as: *"The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity."* (BCSD 1993, p. 8)

The Eco-efficiency concept encapsulates a simple but persuasive understanding that it is not only possible to provide more value with lower environmental impact, but that such a trend is imperative and a burning requirement of contemporary societies. Overall, eco-efficiency rests on some key pillars (Moreira et al. 2010): (1) reduction on materials intensity; (2) minimization on energy intensity in both products and services; (3) reduction on the quantity and dispersion of toxic substances and a cutback on the substances toxicity levels; (4) promotion of closed cycles, remanufacturing, recycling, and other meaningful end-of-life strategies; (5) promotion of use of renewables (energy, materials, etc.), abundant and local resources; (6) extend the durability of products; (7) increase the service intensity.

The rationale for providing more value with less impact, rests on a simple cradle-to-cradle premise, that effectiveness can be progressively or more radically pursued, taking into account full lifecycles, i.e. from extraction to disposal, without unintended armful relocations among lifecycle stages. Overall, this essentially means that waste spurs on any stage and on a number of forms along the product lifecycle, requiring both continuous improvement processes and radical innovation on: (1) product, plant and business-chain design and operation stages; (2) technology, energy and other resources; (3) the consumers' perceptions and needs. For instance, industrial symbiosis might be upheld has one possible strategy for lowering aggregated impacts (of multiple companies).

7.2.4 Lean-Green

The United Nations Environment Programme (UNEP) initiated their Cleaner Production Programme (CP) in 1989 (partnered by the UN Industrial Development Organization branch (UNIDO) from 1994 onwards), which targeted "the continuous application of an integrated preventive environmental strategy applied to processes, products and services to reduce risks to humans and the environment" (UNEP 1996). Both the UNEP/UNIDO and the WBSCD acknowledge that CP and eco-efficiency reinforce mutually (WBCSD/UNEP 1998) to what is widely known as Green (Production); other aligned terminologies include cleaner production, industrial ecology, among others.

More recently, another link has been synergistically established with Lean Manufacturing, which was coined Lean-Green (Maxwell et al. 1993, 1998; Florida (1996); Klassen 2000; Rothenberg et al. 2001; USEPA 2003; Larson and Greenwood 2004; Pojasek 2008; Found 2009; Moreira et al. 2010). This was a radical new venture, since Lean was not specifically designed for eco-effectiveness, but rather to deliver a highly competitive and continuously evolving business approach, that strives to deliver the exact products the consumers want, at the right price, quality and pace. Somehow, the inner principles of the Toyota Production System, later on translated into the western term Lean, endorsed a number of issues akin to Green which cannot be negligible. Since Lean upholds a culture of pursuing perfection, by removing all forms of waste, continuous improvement (*Kaizen*) and radical improvement (*Kaikaku*) along with focus on specifying, delivering and making value flows, and since perfection is surely an ideal state where human race delights in a pristine nature, no waste is produced, and no product/process delivers harmful substances to any kind of being, is not surprise that such reasoning's and aims seem rather familiar and aligned. Although the Lean intents (concerning the environment) seem rather unintentional, and not all aspects can be clearly aligned with those of green production, it may worth further exploration, and an eventual expansion on the breadth and depth of the Lean-Green link.

7.3 Methodology and Data Collection

This chapter is based on a systematic literature review on Sustainability, Lean, Eco-efficiency and Lean-Green concepts. The Sustainability and its symbiotic relationship with the Lean concept are studied in order to clarify the state of the current academic research lines related with this subject, identifying gaps and new research paths.

A good literature review is selective as only selects most relevant past studies, comprehensive because it includes past studies highly relevant, critical because evaluate them as they relate to current study (Neuman 2006). It covers relevant literature on the topic and is not confined to one research methodology, or one set of journals or one geographic region (Webster and Watson 2002).

"A systematic review is a specific methodology that locates existing studies, selects and evaluates contributions, analyses and synthetizes data and reports the evidence in such a way that allows reasonably clear conclusions to be reached about what is and is not known" (Denyer and Tranfield 2009, p. 671). Also it is a replicable, scientific and transparent process that aims to minimize bias (Tranfield et al. 2003). To conduct this review, five steps (Denyer and Tranfield 2009) are necessary: (1) Question formulation, (2) Locating studies; (3) Study selection and evaluation; (4) Analysis and synthesis and (5) Reporting and using the results. The systematic review in this chapter follows the same steps and is summarized in Table 7.1.

The objective of this systematic review was to enhance the knowledge on Sustainability, Lean and Lean-Green concepts and their relationship. By considering this, the question formulated in Table 7.1 emerged.

The search was restricted to papers in the following electronic databases: ISI Web of Knowledge, Scopus, Elsevier (Science Direct), Wiley Online Library (Wiley), Taylor & Francis, Springer and Emerald Insight.

Papers were identified for the period between 2001 until 2015.

For the search criteria, the study was based on the three key words: "sustainability", "eco-efficiency" and "lean-green", in the field of production/manufacturing/

Table 7.1 Steps of the methodology adopted in this chapter

1. Question formulation	Does research on Sustainability, in the field of Production and Operations Management, exhibits a link to that of Lean and/or Eco-efficiency concepts?
2. Locating studies	ISI Web of Knowledge, Scopus, Elsevier (Science Direct), Wiley Online Library (Wiley), Taylor & Francis, Springer and Emerald Insight
	Peer reviewed journal and conferences papers
3. Study selection & evaluation	Period: [2001–2015 (June)]
	Keywords: sustainability, eco-efficiency & lean-green
	Search strings: Sustainability & Lean & Green, Sustainab* & Lean & Green, Sustainability & Lean, Sustainab* & Lean (Article and Review Article, Articles in Press), Sustainability & Green, Sustainab* & Green, (Article and Review Article, Articles in Press, Engineering), Sustainability (refine Engineering and "exclude all others", in "English" and "only papers"), Sustainability (Content Type "Journal" and Topic "sustainability", "engineer", "industrial", "sustainable"), Eco-efficiency & Lean & Green, Eco* & Lean & Green, Eco-efficiency & Lean (Engineering), Eco-efficiency & Green (Engineering), Eco* & Lean (Engineering),
	Eco* & Green (Article and Review Article, Articles in Press, Engineering and Topic: green, production, system, environmental performance, manufacturing system), Lean-Green (refine Engineering and "exclude all others"), Lean-Green (Content Type "journal")
	Inclusion: sustainability, eco-efficiency, lean-green in production/ manufacturing/ operations management/environmental management
	Exclusion: only lean and lean tools papers (not related with sustainability); sustainability to maintain a lean effort implementation. Books, dissertations, unpublished working papers
	Total papers selected: 83
4. Analysis & synthesis	Excel table summing papers discussing sustainability, eco-efficiency, lean-green and just lean
	Excel table summing papers relating sustainability with lean (S&L); sustainability with eco-efficiency (S&E); eco-efficiency & lean (E&L); sustainability and lean and eco-efficiency (S&L&E)
5. Reporting & using the results	Interpretations of the awareness about the link among sustainability, lean, and eco-efficiency recognized by some authors as lean-green paradigm

operations and environmental management. "Lean" word was not chosen as a first keyword because the search would come with a lot of papers discussing only lean, not really related with sustainability. Also, as the objective is to identify if authors recognize the relation among the three keywords selected, some combinations of the three were selected. The search strings identified were: *Sustainability & Lean & Green*; *Sustainab* & Lean & Green*; *Eco-efficiency & Lean & Green*; *Eco* & Lean & Green*; *Sustainab* & Lean*; *Sustainab* & Green*; *Eco-efficiency & Lean*; *Eco-efficiency & Green*; *Eco* & Lean* and *Eco* & Green*. The search was restricted to peer-reviewed journal papers and conference papers.

In this study, Sustainability was only considered in terms of its environmental side, that is to say, in its Eco-efficiency slope. Sustainability in a way of maintaining a Lean implementation effort was not considered. So, all the papers that refer to Sustainability, only in this last meaning, were kept aside. Books, dissertations, unpublished working papers were excluded.

A total of 83 papers were selected attending to the relevance of the title and abstract. They were selected mainly from journals related with production, manufacturing, operations and environmental management.

For the analysis and synthesis, an excel table was used to retain general details of the study like title, authors, journal, publication details, to identify if the papers were in the scope of the study and to identify: the type of the study (literature reviews, case studies, empirical investigation, surveys, conceptual and theoretical models, empirical observations, interviews), the context of the study (verify the context it matters for this review- production/manufacturing/operations and environmental management) and the relation (if any) the authors make of the three keywords selected.

By doing this literature review, two papers were found that resembles the research done for this chapter and that were very useful for this review. These were the papers from Martínez-Jurado and Moyano-Fuentes (2014) and Garza-Reyes (2015). The intention of the first one was to evaluate the state-of-the-art of research into the links between Lean Management, Supply Chain Management and Sustainability. Although, some papers about Supply Chain arose in the review made here, this was not focused because the Lean-Green paradigm is more related with production inside factory doors and not so much related with Supply Chain. The second paper is a systematic review of the existing literature on Lean and Green that aims to provide guidance on the topic, to uncover gaps and inconsistencies in the literature, and finding new paths for research. Sustainability is also considered in this paper, but the author motivation is not that of awareness or unawareness of the link between Sustainability and Eco-efficiency with Lean. This same author reflected about the early stages of the integration of Lean-Green as an integration paradigm of both initiatives. This reinforces the importance of the review reported in this chapter.

7.4 Papers Analysis and Synthesis

Collected all papers in an excel table, it was possible to make some quantitative analysis, namely, number of papers for each keyword researched and papers that simultaneously discuss combinations of them, number of papers by year and by keyword. One of these analysis is presented in Figure 7.1 that shows the number of papers that discussed each keyword, and the keywords combination.

Table 7.2 presents the synthesis of the papers reviewed in this literature review and the links found among them. The table is ordered by the year of the publication (year 2015, first semester only). A “1” implies that the paper discussed the keyword referred and/or combined the different keywords. The final line in the table presents the sums of “1” for each keyword and for each keyword combination.

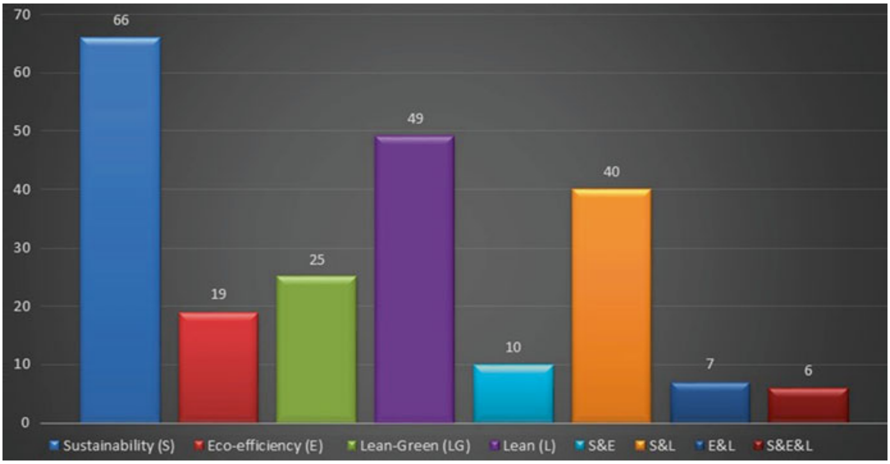

Fig. 7.1 Number of papers for each keyword category and combined categories

Sustainability is the most referred keyword, which is not surprising since the research keyword was that one. It is interesting to note that Lean-Green is referred in 25 papers and sustainability and lean (S&L) surpasses that value, reaching 40 papers. The papers were published on a total of 40 distinct journals. Most papers were published in the *Journal of Cleaner Production* (31 papers, representing 37 % of the total) followed by the International Journal of Production Research (6 papers, just 7 % of the total). In the remaining journals only one or two papers were found.

The number of papers published by each year was also analyzed. The graph depicted on Fig. 7.2 presents those figures. It is of no surprise that the last five years (the number of papers for 2015 is only from the first semester), for the keywords selected, register an increase in the number of papers, as the interest for sustainability issues and approaches grown.

The exact figures on the search using each keyword, within each year, are depicted on Fig. 7.3. It is rather clear that in a short period of time, e.g. the last decade (2005–2015), the keywords occurrence, evolved from essentially absent, at the beginning of that period, to a point where a significant number of scientific papers, found on several journals, can be observed.

Additionally, it was analyzed the type of research methodology used. The higher greatest share (31 %) of papers (26) described case studies.

7.5 Findings and Discussion

The ongoing study shown that the sustainability and the eco-efficiency concepts are not immediately associated to that of lean. A small percentage of the papers (30 %) recognize the Lean-Green a joint approach. Some others authors recognize the

Table 7.2 Results of papers reviewed: authors' names, year and keywords referred and combined

#	Authors	Year	Sustainability	Eco-efficiency	Lean-Green	Lean	S&E	S&L	E&L	S&E&L
1	Rothenberg & Maxwell (2001)	2001	1		1	1		1		
2	Schaltegger & Synnestvedt (2002)	2002		1						
3	Bleischwitz (2003)	2003		1						
4	Ginsberg & Bloom (2004)	2004	1		1					
5	Larson & Greenwood (2004)	2004		1						
6	Kleindorfer et al. (2005)	2005	1		1	1		1		
7	Corbett & Klassen (2006)	2006	1			1		1		
8	Lapinski et al. (2006)	2006	1			1		1		
9	Scoones (2007)	2007	1							
10	Chen et al. (2010)	2010				1				
11	Fernández-Viñé et al. (2010)	2010		1						
12	Miller et al. (2010)	2010	1			1		1		
13	Mollenkopf et al. (2010)	2010	1		1	1		1		
14	Moreira et al. (2010)	2010	1	1	1	1	1	1	1	1
15	Paju et al. (2010)	2010	1			1		1		
16	Brochardt et al. (2011)	2011		1						
17	Eroglu & Hofer (2011)	2011				1				
18	Otsuki (2011)	2011	1							
19	Vinodh et al. (2011)	2011	1			1		1		
20	Yang et al. (2011)	2011	1			1		1		
21	Azevedo et al. (2012)	2012	1		1	1		1		
22	Jänicke (2012)	2012	1							
23	Koskela & Vehmas (2012)	2012		1						

24	Aguado et al. (2013)	2013	1			1		1		
25	Bréchet & Sylvette (2013)	2013		1						
26	Diaz-Elsayed et al. (2013)	2013			1	1				
27	Fernández-Viñé et al. (2013)	2013		1						
28	Hajmohammad et al. (2013)	2013	1			1		1		
29	Jabbour et al. (2013)	2013	1			1		1		
30	Maia et al. (2013)	2013	1	1		1	1	1	1	1
31	Sobral et al. (2013)	2013		1	1	1			1	
32	Taylor et al. (2013)	2013				1				
33	Tseng et al. (2013)	2013	1		1	1		1		
34	Wu et al. (2013)	2013	1			1		1		
35	Bogue (2014)	2014	1							
36	Bolis et al. (2014)	2014	1							
37	Chiarini (2014)	2014	1			1		1		
38	Clune & Lockrey (2014)	2014	1							
39	Dhingra et al. (2014)	2014	1		1	1		1		
40	Faulkner & Badurdeen (2014)	2014	1			1		1		
41	Galeazzo et al. (2014)	2014	1		1	1		1		
42	Johansson & Sundin (2014)	2014	1		1	1		1		
43	Kurdve et al. (2014)	2014	1			1		1		
44	Lodhia &Martin (2014)	2014	1							
45	Longoni et al. (2014)	2014	1							
46	Lorek & Spangenberg (2014)	2014	1							

(continued)

Table 7.2 (continued)

#	Authors	Year	Sustainability	Eco-efficiency	Lean-Green	Lean	S&E	S&L	E&L	S&E&L
47	Martíez-Jurado & Moyano-Fuentes (2014)	2014	1		1	1		1		
48	Pampanelli et al. (2014)	2014	1		1	1		1		
49	Rebelo (2014)	2014	1							
50	Verrier et al. (2014)	2014	1		1	1		1		
51	Wong et al. (2014)	2014				1				
52	Wong & Wong (2014)	2014	1			1		1		
53	Greco et al. (2015)	2015	1							
54	Jasti & Kodali (2015)	2015				1				
55	Lai et al. (2015)	2015	1							
56	Piercy & Rich (2015)	2015	1		1	1		1		
57	Qu et al. (2015)	2015	1							
58	Sengupta et al. (2015)	2015	1							
59	Alves & Alves (2015)	2015	1			1		1		
60	Ball (2015)	2015	1		1	1		1		
61	Chen et al. (2015)	2015	1							
62	de Pauw et al. (2015)	2015	1	1			1			
63	Esfandyari et al. (2015)	2015	1		1	1		1		
64	Garza-Reyes (2015)	2015	1	1	1	1	1	1	1	1
65	Glover et al. (2015)	2015	1			1		1		
66	Greinacher et al. (2015)	2015			1	1				
67	Gupta et al. (2015)	2015	1			1		1		
68	Harik et al. (2015)	2015	1							

69	Henriques & Catarino (2015)	2015	1	1			1			
70	Kasava et al. (2015)	2015	1			1		1		
71	Kim et al. (2015)	2015	1							
72	Kruse et al. (2015)	2015			1	1				
73	Kurdve et al. (2015)	2015	1	1	1	1	1	1	1	1
74	Ng et al. (2015)	2015	1		1	1		1		
75	Nieuwenhuis & Katsifou (2015)	2015	1	1	1	1	1	1	1	1
76	Pappas et al. (2015)	2015	1							
77	Rashidi & Saen (2015)	2015	1	1			1			
78	Sangeeth Kumar & Gokulachandran (2015)	2015	1	1			1			
79	Vimal et al. (2015a)	2015	1							
80	Vimal et al. (2015b)	2015	1	1		1	1	1	1	1
81	Wagner (2015)	2015	1							
82	Wu et al. (2015)	2015	1		1	1		1		
83	Zaman (2015)	2015	1							
		Total	66	19	25	49	10	40	7	6

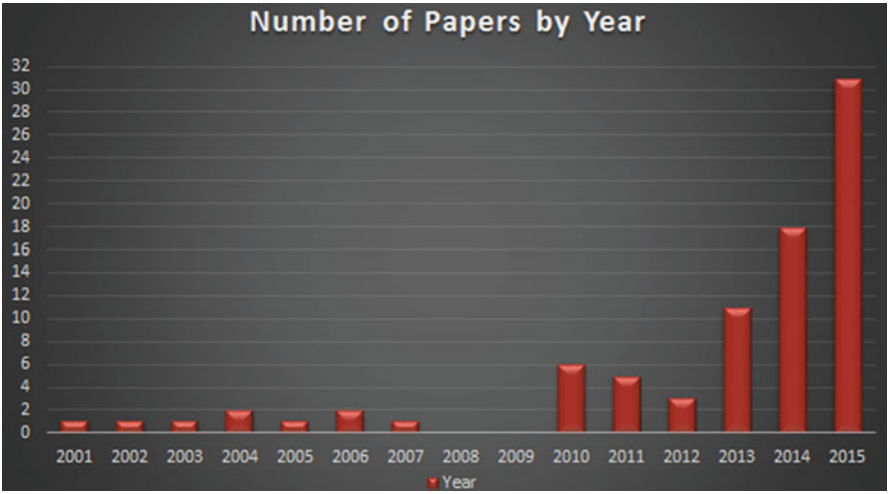

Fig. 7.2 Number of papers by year

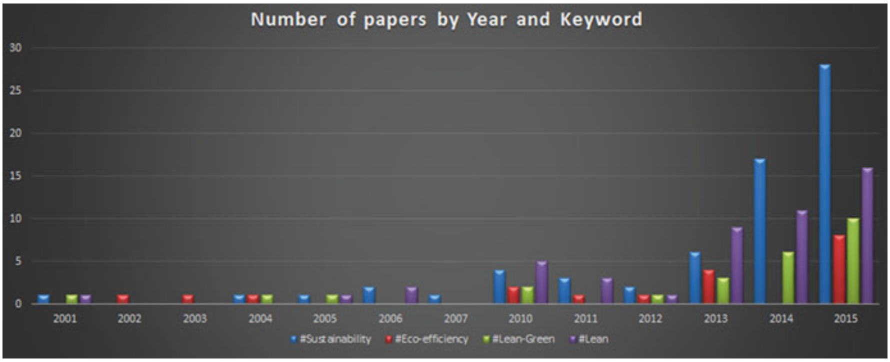

Fig. 7.3 Number of papers by year and by keyword

Lean-Green link, although not explicitly, as denoted by overlapping the results of the search on sustainability and lean (S&L), whose percentage of 48 % is expressed in the Venn diagram represented in Figure 7.4. A similar reasoning could be applied to expand the implicit results of the study, by overlapping the zones of Eco-efficiency and Lean (E&L) with an additional 8 %, since the Eco-efficiency concept is clearly aligned with the Lean principles. Overall, only 7 % of the papers address all the considered concepts, e.g. Sustainability, Eco-efficiency and Lean (S&E&L), as depicted in the central spot of the Figure 7.4.

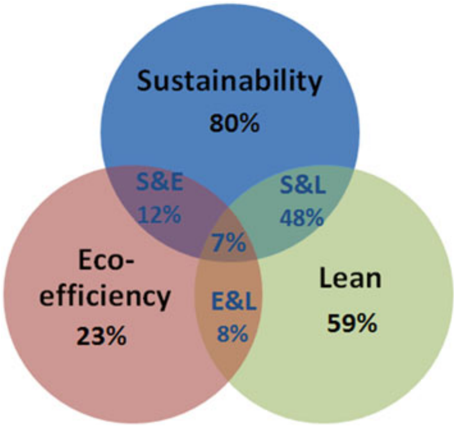

Fig. 7.4 Venn diagram with keyword categories and overlapping of combined categories

From the total number of papers on Lean-Green (25), only seven were considered case studies, fundamentally reporting the application of this paradigm on companies. This sample shows that in practice there are few examples where the explicit use of this joint paradigm has made it to the shop-floor. A more common situation is that of having a clear endorsement of issues related to Green Production in business cases for Sustainable Development (Holliday et al. 2002) or Lean Production, in isolation. The intention for improvement derives from the need to be more efficient or more sustainable, but rarely considering that one might lead to effective gains on akin to the other.

Although the Lean-Green paradigm has been initially suggested in 1993, and more recently investigated by a number of different authors, as shown on Table #.2 (column Lean-Green), a number of recent studies hold a position that this paradigm is still in its infancy (Moreira et al. 2010; Maia et al. 2013; Jabbour et al. 2013; Kurdve et al. 2014; Abreu and Alves 2015; Garza-Reyes 2015; Ng et al. 2015; Harik et al. 2015; Alves and Alves 2015). The integration and implementation of Lean and Green practices (simultaneously), especially when the resources are limited, represent a challenge for companies, which, according to some of the studies, requires a supporting framework and a cultural transformation. Additionally, some authors consider that efficient manufacturing along with environmental initiatives, provide favorable conditions for maintaining a continuous improvement quest for remaining competitive and/or gaining competitive advantage, while providing operational versatility to respond quickly to volatile markets.

These findings are based on a systematic review of the literature that resulted in 83 papers which were subsequently analyzed and synthetized. The methodology used was thorough explained on Sect. 7.3. The authors consider that the study results provide sufficient evidence for the findings presented. These can be easily mimicked while achieving similar results grounded that the setting for the study is retained.

7.6 Conclusions

A systemic literature review was conducted to investigate the awareness and use of the symbiotic relationship of the concepts of Sustainability, Lean and Green Production and Eco-efficiency within the field of Production and Operations Management. The review was conducted over the 2001–2015 (first semester) timeframe, whose output was found to pertain to about 40 distinct scientific journals, on 83 papers in total.

The clearest and most frequent relation found, which spurred from the results of the study, was that of a correlation on the use of the Lean and Green concepts, followed by the Sustainability and Eco-efficiency link. Most papers (37 %) pertained to the *Journal of Cleaner Production*, while the International Journal of Production Research ranked second, but much further down the line, with about 7 % of the papers only. The yearly frequency denotes that the sustainability agenda has been progressively gaining momentum, with the last two and half years (2013 to the first semester of 2015) representing about 72 % of the total number of papers, with 11, 18 and 31 papers published, respectively in 2013, 2014 and on the first half of 2015. Bearing in mind that: (1) the Lean movement is spreading both geographically and in domains of application (2) Sustainability is on the top of the agenda of companies, government agencies and individuals, and (3) the study shown a clear growth on the combined endorsement of both issues by the scientific community, it is rather logical that this trend will develop further in the foresighted future.

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Chapter 8
Integrating Sustainability Metrics in the Supply Chain Performance Measurement System

Luis Miguel D.F. Ferreira and Cristóvao Silva

Abstract Sustainability impact of business activities, taking in account the three dimensions of the triple-bottom-line (economical, environmental and social), has become an important issue in the last years due to growing public awareness, and the introduction of legislations mainly in developed countries. From an industrial perspective, sustainable development must be extended beyond organizational boundaries to incorporate a supply chain approach.

This paper aims to contribute to the theoretical body of literature by proposing a five step model to supply chain sustainability performance assessment. The model is based on the Balanced Scorecard framework to define the company sustainability strategy and uses Global Reporting Initiative (GRI) and ISO 14031 indicators to measure the sustainability performance of it upstream supply chain.

The proposed model helps companies in the analysis of trade-offs among economic, environmental and social performance of supply chains, providing directions to improve each of the considered indicators.

8.1 Introduction

Organizations are increasingly aware and concerned with the environmental and social impact of their business activities (Carter and Easton 2011; Gold et al. 2010; Winter and Knemeyer 2013; Yu and Li-Ping Tang 2011). The focus on supply chains

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is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery until the customer. However, this demands for the integration of issues and flows that extend beyond the core of supply chain management (Linton et al. 2007).

Sustainability impact of business activities has become an important issue in the last years due to growing public awareness, and the introduction of legislations mainly in developed countries (Lau 2011). To address these stakeholders' concerns, manufacturers have adopted different strategies that focus on internal operations (Vachon and Klassen 2006). However, in recent years, more and more companies are introducing and integrating sustainability issues into supply chain management processes by auditing and assessing suppliers (Handfield et al. 2005). In this way they seek to ensure that they have effective tools not only for measuring sustainability performance of their suppliers but also to help choose them for new projects/products or for carrying out action plans to improve their performance (Naini et al. 2011; Olugu et al. 2011).

However, traditionally the performance measurement of supply chain has been oriented around cost, time and accuracy criteria (Thakkar et al. 2009; Bhagwat and Sharma 2007; Gunasekaran et al. 2001). Hervani et al. (2005) argue that there are difficulties in measuring performance within organizations and several reasons are presented to justify the lack of systems to measure performance across organizations: non-standardized data, poor technological integration, geographical and cultural differences, lack of agreed upon metrics, or poor understanding of the need for inter-organizational performance measurement. Several authors argue that performance measurement in supply chains is difficult, especially when looking at numerous tiers within a supply chain (Gunasekaran et al. 2004; Hervani et al. 2005; Lehtinen and Ahola 2010). Overcoming these barriers is not a small issue, but the long-term sustainability and competitiveness of organizations relies on successful implementation of performance measurement systems (Olugu et al. 2011; Hervani et al. 2005).

The literature shows that most models for measuring sustainability performance focus on the measurement of single internal functions or activities instead of measuring across the supply chain, and just a little part of the research reported has approached the topic taking in account all the dimensions of the triple-bottom-line (TBL). The application of sustainability principles into supply chains is an evolving research area currently suffering from a scarcity of established theories, models and frameworks (Ahi and Searcy 2015; Brandenburg et al 2014; Wong et al. 2015). Thus, the main objective of this paper is to propose a framework for sustainability supply chain performance measurement. The contribution of this study relies on the development of a model for the evaluation of the sustainability performance of the upstream supply chain.

The article is divided into four sections. This section seeks to provide an introduction to the topic in question and define the objective of the study. The second section presents a literature review on supply chain management and sustainability and models for sustainable supply chain performance measurement. Section 8.3 presents a framework for the measurement of sustainable performance of a supply chain. Finally, the main conclusions of the study are drawn in Sect. 8.4.

8.2 Literature Review

8.2.1 Supply Chain Management and Sustainability

The concept of Supply Chain Management was born and brought a new facet to company management in the 1980s (Alfalla-Luque and Medina-López 2009). Supply chain management is the coordination and management of a complex network of activities involved in delivering a finished product to the end-user or customer. Supply chain management has gained a strategic relevance as a source of competitive advantage (Fine 1998) and managing value on supply chains has become critical for company survival and growth. However, cost efficiencies and service targets are not the only strategic drivers of business developments in today's competitive environments.

Several authors argue that the rising pressure toward TBL thinking is leading the integration of sustainability considerations into business and supply chain strategies (Kleindorfer et al. 2005; Seuring and Müller 2008). A focus on supply chains is a step towards the broader adoption and development of sustainability (Linton et al. 2007). Moreover, the focus on the supply chain enables the development of topics related to sustainability, as the supply chain encompasses the different stages ranging from the initial processing of raw materials to delivery to the end customer (Stonebraker et al. 2009; Vasileiou and Morris 2006). It is therefore essential to investigate the operational implications and how organizations can incorporate sustainability issues into their management practices (Jiménez and Lorente 2001) and create competitive advantage (Markley and Davis 2007).

Sustainable supply chain management (SSCM) has emerged as an approach that combines the general aims of supply chain management with the overarching goals of sustainability, i.e. economic, social and environmental performance. Carter and Rogers (2008) state that SSCM is an extension to traditional supply chain management that also includes TBL thinking. Taticchi et al. (2013) argue that sustainable supply chains are a key component of sustainable development in which the environmental and social criteria need to be fulfilled by supply chain members to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria. This implies that companies have to satisfy multiple and conflicting objectives as maximizing profits while reducing operating costs, minimizing the environmental impacts and maximizing the social well-being.

However, the successful implementation and application of those concepts faces many challenges. Carter and Rogers (2008) mentions the missing balance between the sustainability dimensions which are often considered independently rather than interdependently. Therefore, accurate performance measurement is essential when trying to assess the effectiveness and usefulness of sustainability related decisions. However, sustainability remains an abstract concept for many companies and support mechanisms for SSCM, e.g. for performance measurement, also remain scarce and more research efforts are required (Grosvold et al. 2014; Schaltegger and Burritt 2014; Varsei et al. 2014). Vasileiou and Morris (2006) using the potato supply chain as a case study state that "objective, verifiable measures of sustainability are required to guide and report supply chain performance, and that this requires the collaboration of all supply chain agents".

8.2.2 Evaluation Models for Sustainable Supply Chain Performance Measurement

Sustainable supply chain management looks to improve environmental and social performance of companies in the supply chains (Schaltegger and Burritt 2014). Brandenburg et al. (2014) argue that SSCM address the challenges of sustainability risks, opportunities and trade-offs from a business and value-chain perspective by bringing upstream and downstream partners to the boundary of investigation and management to improve sustainable performance of supply chains. Due to their contractual binding to the company, customers and suppliers are seen as it most relevant and influential stakeholders (Kovács 2008), which calls for a supply focus when dealing with sustainability. However, the integration of sustainability into firms requires action that exceeds organizational boundaries (Seuring and Gold 2013).

Pagell and Shevchenko (2013) argue that sustainability should be integral to management of supply chains. The challenge is to move from managing unsustainable supply chains in a (more) sustainable manner to managing sustainable supply chains. However, little attention has been given to measuring performance, providing an inter-organizational perspective involving the key stakeholders, in the context of sustainable supply chains (Taticchi et al. 2013) and to the relation between sustainability performance measurement and the improvement of supply chain management (Schaltegger and Burritt 2014). Bjorklund et al. (2012) argue that most of studies measure single internal functions or activities instead of measuring across the supply chain. Vasileiou and Morris (2006) state that issues of sustainability have tended to concentrate on a particular stage of the supply chain, rather than on the supply chain as a whole.

However, in a supply chain, a significant number of actors (suppliers, producers, consumers, logistics providers, as well as services suppliers are the main players) influence not only the costs but also the associated impacts. All these actors perform activities that impact business and it environment. Thus, it is necessary to create models that make possible to measure the sustainability performance of the supply chain, promoting also the monitoring of indicators that support decision-making and management (Dey and Cheffi 2012; Naini et al. 2011; Olugu et al. 2001; Schaltegger and Burritt 2014; Taticchi et al. 2013).

Some authors argue that the implementation of sustainability initiative can result on substantial costs (Pullman et al. 2009; Wu and Pagell 2011; Ross et al. 2012), but, as stated by Varsei et al. (2014), companies might be able to justify the long-term economic benefits of designing environmental and social initiatives at the supply chain level. To do so, more sophisticated decision-making tools and techniques are required for firms to perform sustainability assessments across supply chains (Seuring 2013). Searcy (2012, p. 240) argues that "a robust sustainable performance measurement system should help decision makers navigate the challenges of corporate sustainability by helping them to better understand their current situation and their desired end state".

Performance management in supply chains is not a new topic (Cagnazzo et al. 2009). In fact, supply chain performance measurement has seen increased attention due to the changing competitive nature from individual organization competition to supply chain competing against each other (Christopher 1998). Shepherd and Gunter (2005), in a review about the topic, identified the limits of available performance measurement systems for supply chains: lack of connection with strategy; focus on cost to the detriment of non-cost indicators; lack of a balanced approach and lack of system thinking. Lehtinen and Ahola (2010) go one step further and, argue that there are incompatibilities between the known principles of performance measures and supply chain dynamics. Taticchi et al. (2013) argue that less research has focused on the development of integrated frameworks for measuring the performance of supply chains.

Recently, many organizations started to measure the sustainability of their business mainly with three goals: transparency and communication to stakeholders, improvement of their operations and strategy alignment. Within this context, several metrics and frameworks have been proposed by industry such as Global Report Initiative (2013), the IChemE (2003) proposed by the Institution of Chemical Engineers, the Carbon disclosure Project (CDP 2013) or the International Federation of Accounts (IFAC 2013), while academia has produced revised versions of traditional frameworks such as the Sustainability Balanced Scorecard (Burritt and Schaltegger 2014; Hansen and Schaltegger 2014; Reefke and Trocchi 2013; Searcy 2012).

The Sustainability Balanced Scorecard (SBSC) is based on the Balanced Scorecard (BSC) a framework that was developed by Kaplan and Norton (1992). The main objectives of the BSC are: to clarify and translate the vision and strategy; to communicate and associate objectives and strategic measures; to plan, establish goals and align strategic initiatives; to improve the feedback and the strategic learning. The BSC is a multidimensional performance measurement and management framework organized hierarchically with four performance perspectives (finance, customer, internal processes, and learning and growth) aimed at balancing financial and non-financial, short-term and long-term, as well as qualitative and quantitative success measures. These perspectives are interlinked by cause-effect relationships (Fig. 8.1).

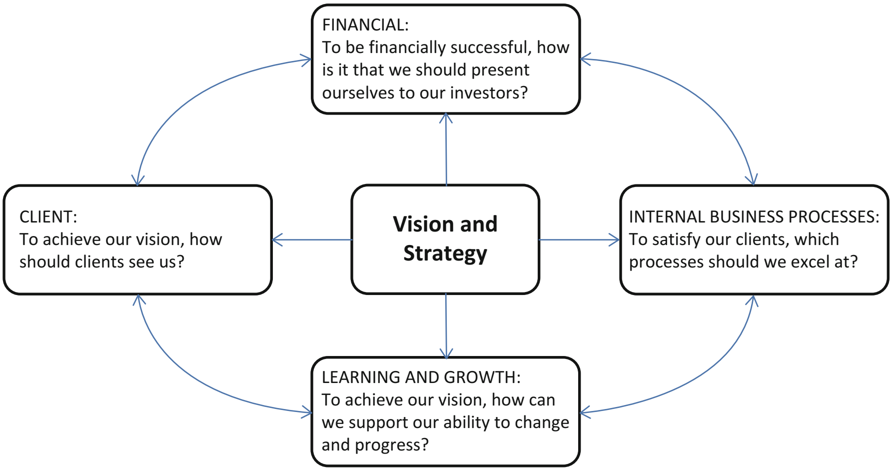

Fig. 8.1 Viewpoints of the BSC (adapted from Kaplan and Norton 1992)

As many environmental and social issues are non-financial and often influence an organization over the long term, academics (Dias-Sardinha and Reijnders 2001; Epstein and Wisner 2001; Figge et al. 2002; Hervani et al. 2005; Hsu et al. 2011; Hsu and Liu 2010; Hubbard 2009; Nikolau and Tsalis 2013; Länsiluoto and Järvenpää 2008; Schaltegger and Wagner 2006) considerer the BSC an appropriate tool to account for sustainability issues. In this process, sustainability management benefits from the advantages of using the BSC (Reefke and Trocchi 2013). At the same time, the BSC as a system of strategic management becomes more complete by incorporating the treatment of the relevant strategic aspects of sustainability.

Several authors have pointed out limitations to the use of the BSC (Bhagwat and Sharma 2007; Jensen 2001). The following criticisms are noteworthy: the efficiency of the BSC can be limited by "*interpretation effects*", in implementing the strategy, priority may be given to the use of financial indicators rather than non-financial indicators, some stakeholders are not accounted for and the formulation of the BSC can depend on the relative power of the various groups involved.

The literature regarding the inclusion of environmental and social dimensions into the BSC points to four options (Epstein and Wisner 2001; Figge et al. 2002): (1) adding a sustainability perspective (add-on); (2) partial integration into existing perspectives (partly integrated); (3) complete integration into existing perspectives (broadly integrated); (4) simultaneous integration into existing perspectives while adding a dedicated perspective (extended).

Hansen and Schaltegger (2014) argue that for an integration of sustainability into mainstream performance management and measurement, simply adding a separate sustainability perspective is the "last far reaching" of the four options.

Besides that sometimes the integration of sustainability in the BSC goes along with reframing and relabeling perspectives. For example, customer perspective is broadened to include additional stakeholders leading to "customers and external stakeholders" (Johnson 1998), or "customer and suppliers" (van Marrewijk 2004). The sustainability balanced scorecard should be understood as a dynamic concept (Hansen and Schaltegger 2014).

Although extending the BSC perspectives towards other stakeholder groups (e.g. suppliers) can be an important step, corporate sustainability is only advanced if it is explicitly addressed in these stakeholders perspectives (for example by requiring environmental and social practices in the supply chain). Burritt and Schaltegger (2014, p. 339) in a recent review presented several "clear avenues" for future research and the first one is the recognition that there is a "new entity for accounting—the supply chain". This new entity involves movement from narrow accounting for firms in manufacturing or services industries towards broader measurement and disclosure required for supply chains. Burritt and Schaltegger (2014) argue about the need to specify about what sustainability performance entails in the context of the organization, its business environment and social setting. Such specification will in many cases lead to a focus on a number of prioritized aspects of sustainability which, if individually improved will improve the overall sustainability performance. Based in the identification of those key sustainability issues the requirements for which data need to be gathered, classified, accumulated and used in different decision settings can be specified.

Hervani et al. (2005) propose a balanced scorecard-type framework to implement a green supply chain management performance measurement system. Their model consider approximately 60 performance indicators which have been pointed out as a drawback to it implementation (Shaw *et al*. 2010). In fact, there is no rule to the right number of measures to include in the BSC but, as stated by Epstein and Weisner (2001), too many performance indicators can distract from pursuing a focused strategy. Gopalakrishnan et al. (2012) presented a ten point guide to best practice for the deployment of sustainability in supply chains. The authors argue that KPI need to be identified and ranked according to priority based on management perception of the challenges. Naini et al. (2011) proposed a mixed performance measurement system, for environmental supply chain management; using a combination of evolutionary game theory and the Balanced Scorecard (the four original perspectives are used). The method was applied in a case study in Iran's biggest auto industry supply chain. Erol et al. (2011) proposed a multi-criteria framework based on fuzzy entropy and fuzzy multi-attribute utility for measuring sustainable performance of a supply chain. However, the authors mention that reducing all the aspects of sustainable supply chain to a single unit using a multi-criteria framework may not be sufficient to satisfy all the needs of decision makers. Reefke and Trocchi (2013) propose a customized scorecard design and development process, based on BSC, for sustainable supply chains.

The review of the literature has evidenced the need to develop integrated tools and frameworks for measuring sustainable supply chain performance in respect of the TBL concept (Taticchi et al. 2013, p. 4). Bjorklund et al (2012) state there is a need of measuring across the supply chain and to apply more process oriented measures. The majority of the reviewed frameworks for measuring SSCM performance focus on the evaluation of the organization itself and just a little part of the research reported has approach the topic taking in account all the dimensions of the TBL (Taticchi et al. 2013; Vasileiou and Morris 2006). Besides, according to Walker and Jones (2012) there is a wide gap between what practitioners say and do about SSCM in reality. In a recent literature review Bitici et al. (2012) state that "sustainability agenda needs to be explored as part of the whole rather than as a standalone, exclusive and independent performance-measurement system within the organization or value chain".

We aim to address this gap in the current literature and propose a framework that could be used as an assessment tool, in a multi-stakeholder environment, for the measurement of performance in sustainable supply chains. The proposed framework relies on the BSC approach and use the GRI and ISO 14031 to define the performance indicators to be used. In order to facilitate the management of the indicators and avoid introducing additional complexity to both the company's general performance evaluation system and the system to be created, it was decided to opt for the development of a specific and adapted BSC to measure the sustainability supply chain performance and the data that will feed the system will be collected directly from first-tier suppliers. This process of data collection along the supply chain, looking behind the single firm boundaries, is aligned with Seuring and Gold (2013) recommendations.

8.3 The Sustainability Balanced Scorecard Framework for Supply Chain Performance Measurement

The benchmarking of sustainability practices requires intra and inter-organizational practices with a set of environmental, social and economic performance outcomes (Hong et al. 2012). In practice those indicators may be used either by stakeholders outside the company (as in the case of the supply chain), or internally by the company (at a departmental level), in order to establish a process for reducing the impacts of their products and processes.

Taticchi et al. (2013) argue that the success of any sustainability programme lies in visibility (and hence in measurement) of sustainability risks through the supply chain and standards to mitigate them, developing effective ways to assess, compare, benchmark, correlate practices to sustainability indicators is mandatory. The supply chain perspective is so important because the sustainability risk begins not with the company products, but with its suppliers. Transparent and efficient measurement are fundamental not only to effective communicate performance both to internal stakeholders and to the market, but also to have trajectories towards improvement. The ultimate goal of the assessment of sustainability performance is to ensure that industrial activities move towards sustainability in an acceptable manner to both society and the environment (Linton et al. 2007).

According to Cohen and Roussel (2004), the definition of an appropriate set of metrics allows the performance of the activities in the supply chain to be evaluated, contributing to the diagnosis of problems and improvement in the decision making processes. The indicators to be selected for measurement of supply chain sustainability must therefore cover all three dimensions of sustainability. Clift (2003) argues that although general indicator frameworks can be developed, indicators need to be established on a sector-by-sector or even case-by-case basis.

In order to address the lack of structured systems for the measurement of sustainable performance of a supply chain the model described below was developed. Although the proposed model is supposed to be independent of the general company BSC, it forms a natural part of the management system, linking up with the various systems and giving decision making signals to the top management, as well as logistics, purchasing and environmental managers. This option is aligned with Taticchi et al. (2013) recommendation that argue that supply chain measurement frameworks should interface with measurement systems developed for single organizations yet maintaining the cross-view required to address sustainable supply chain context. Besides that it is important to develop research models and frameworks that take into consideration specific country and industry characteristics.

The proposed model—**Sustainability balanced scorecard framework for Supply Chain Performance Measuremen**t—is based on the logic of the BSC to evaluate the performance of the supply chain, while using ISO 14031 and the GRI guidelines to define the indicators. The model is displayed in Fig. 8.2. The phases that make up the proposed model are: (1) Modeling the supply chain process; (2) Definition of the strategic map; (3) Identification of aspects and their associated indicators for monitoring; (4) Collection of the data; (5) Data processing and implementation, including monitoring and a PDCA Cycle.

There now follows a description of the different phases suggested for the model.

8.3.1 Phase 1: Modeling The Supply Chain Process

The proposed approach starts with the study of the supply chain in order to understand its flows, stakeholders and particularities. Process mapping is essential to understand how processes operate and where responsibility lies (Collier and Evans 2007, p. 273). Accurate process mapping allow for the identification and recording of all related

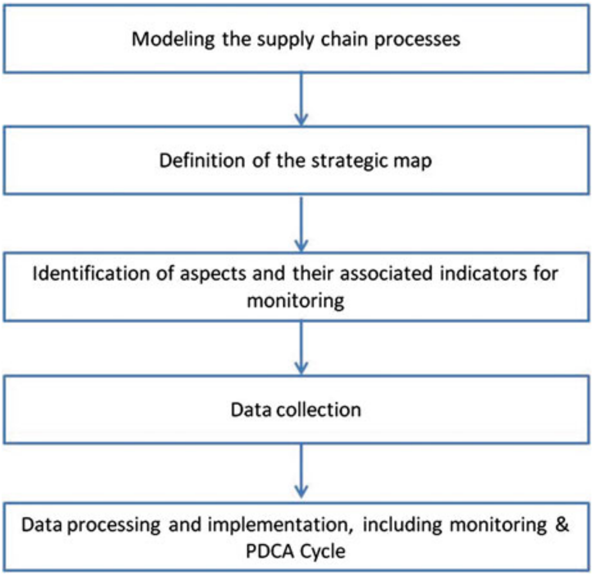

Fig. 8.2 Model of sustainability balanced scorecard for supply chain performance measurement

activities, thus ensuring that proper data collection takes place. In order to consider the supply chain as a whole, the different actions and processes performed by different companies should be correctly recorded on the process maps so that the role (and hence impacts) a company plays in the system can be examined.

8.3.2 Phase 2: Definition of the Strategic Map for the Supply Chain

The initial formulation of the SBSC depicts the strategy of the company distributed over the four perspectives which are interlinked by cause-effect relationships. It is important to remember that the casual relationship between the strategically relevant aspects identified does not exist only between lagging and leading indicators within one perspective. Rather, all aspects and indicators have to be directly or indirectly linked towards the financial perspective.

The option for a strictly hierarchical SBSC intends to emphasize the original character of the conventional BSC and the need for a top-down arrangement of performance perspectives with accurate linkages of strategic core issues and performance drivers, all of which ultimately contribute to financial objectives (Hansen and Schaltegger 2014). The strict hierarchy is considered necessary for full embedding environmental, and social aspects into general management, and for preventing the SBSC as being perceived as a mere public relations exercise

(Zingales et al. 2002). With this option the environmental and social objectives have to, directly or indirectly, contribute to financial objectives.

The process of formulating a SBSC can be shown graphically by using a strategy map (Kaplan and Norton 2001). In such a strategy map, all economic, environmental, and social aspects which have been identified as strategically relevant are represented in the hierarchical network of cause-and-effect chains. The definition of the strategy map should take into account the strategies of the business, supply chain management and sustainability management. Moreover, Hervani et al. (2005) argues that measures are best developed with derivation from and links to corporate strategy and that the performance measurement for SCSM must fit with the strategy of the supply chain. In order to facilitate the management of the indicators and avoid introducing additional complexity, in the proposed model, the option is to develop a specific SBSC to monitor the evolution of the performance of the supply chain, see Fig. 8.3. This option is aligned with Taticchi et al. (2013) recommendations.

In order to develop the strategy map it is necessary to involve a multidisciplinary team of internal stakeholders, with elements of management as well as the engineering, logistics, environmental, quality, purchasing and production departments and external stakeholders (suppliers and NGO). Once the identification and alignment of the strategically relevant aspects has been done, the next step is to define indicators, targets and measures in order to control and steer corporate performance towards long term success and the achievement of strong corporate contributions to sustainability in the supply chain.

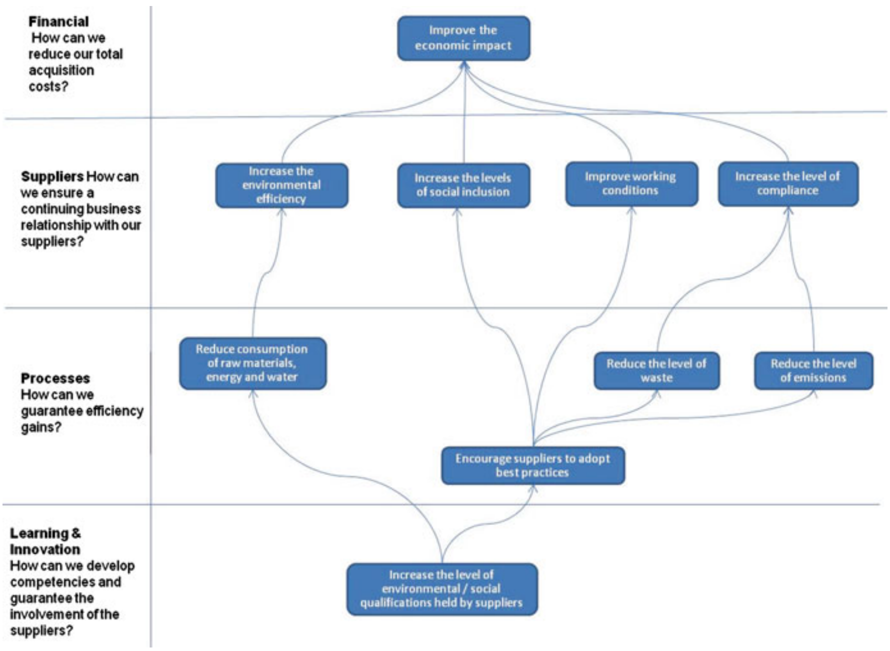

Fig. 8.3 Illustrative example of a strategy map for the SBSC

8.3.3 Phase 3: Identification of Aspects and Their Associated Indicators for Monitoring

The sustainable development agenda has introduced a plethora of new aspects for which the organizations should be accountable. These include accounting for issues that are outside of the direct control of the organization, that are based on value judgments and are difficult to characterize (Keeble et al. 2003). Moreover, the measurement of performance is complicated by the fact that many organizations have different business streams, functions and are involved in different projects.

Indicators perform various functions which may lead to better decisions and more effective actions towards the goals of sustainable development. However, the development of sustainability indicators is not an easy task (Keeble et al. 2003). Those indicators should reflect the business realities, values and culture of the organization, and as such their development should not be constrained to prescribed methodologies or standards. Moreover, it is necessary to the organization to go through the development of indicators since this will help the organization to develop a sense of ownership over the results, fully realize the benefits of organizational learning, and ensure the results truly reflect the values and business situation of the company (Searcy et al. 2005). Geibler et al. (2010) argue that a broad stakeholder's consultation for the identification of appropriate indicators assists in broadening the company's assessment of current as well as future concerns. Moreover, at a strategic level, it protects a company from competitors and provides guidance on investment decisions.

Since the development of indicators can be a complex process, Searcy et al. (2005) argue that the indicator design process should be developed using a systemic approach, proposing a six-step procedure linked to the plan-do-check-act (PDCA) cycle of continuous improvement. Some tailored sustainability indicator sets have been developed (Azapagic 2004; Krajnc and Glavic 2003; Krajnc and Glavic 2005; Labuschagne et al. 2004), however only few have an integrative focus on measuring environmental, economic and social dimensions (Labuschagne et al. 2005; Singh et al. 2009; Veleva and Ellenbecker 2001). The internationally standards (ISO 14031, GRI or WBCSD Eco-efficiency metrics are the most well know examples) can play an important role in informing the development of appropriate indicators. Nevertheless, from the point of view of Dowse (2005) sustainability measures and reports, in most cases, have little relevance to the daily realities of business.

Bearing in mind this, a different set of sustainability indicators should be suggested attending to the following methodology/criteria: (1) the TBL perspective is adopted therefore balancing the relationships between economic, environmental, and social needs; (2) the social and economic indicators are selected having as reference the version G4 of the Global Reporting Initiative (GRI); (3) the environmental indicators are aligned with the proposed operational indicators of the ISO 14031; and (4) a set of mandatory characteristics of the selected indicators was followed (objectives, understandable, worktables and measurable indicators). Table 8.1 presents an illustrative set of sustainability indicators that could be used in the model.

Table 8.1 Illustrative set of sustainability indicators that could be used in the model

Sustainability BSC perspective	Sustainability indicators	Source
Suppliers	Total number and volume of significant spills	GN—EN24
	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with environmental laws and regulations	G4—EN29
	Total environmental protection expenditures and investments by type	GN—EN31
	Total number and rates of new employee hires and employee turnover by age group, gender and region	G4—LA1
	Type of injury and rates of injury, occupational diseases, lost days, and absenteeism, and total number of work-related fatalities, by region and by gender.	G4—LA6
	Workers with high incidence or high risk of diseases related to their occupation	G4—LA7
	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations	G4—SO8
Financial	Direct economic value generated and distributed	G4—EC1
	Proportion of Spending on local suppliers at significant locations of operations	G4—EC9
	Ratios of Standard entry level wage by gender compared to local minimum wage at significant locations of operations	G4—EC5
	Total number of employees	G4—9
Process	Materials used by weight or volume	G4—EN1
	Percentage of materials used that are recycled input materials	G4—EN2
	Energy consumption within the organizations	G4—EN3
	Total water withdrawal by source	G4—EN8
	Direct Greenhouse Gas (GHG) emissions (scope 1)	GN—EN15
	NOX, SOX, and other significant emissions	GN—EN21
	Total water discharge by quality and destination	GN—EN22
	Total weight of waste by type and disposal method	GN—EN23
	Percentage of new suppliers that were screened using environmental criteria	GN—EN32
	Percentage of new suppliers that were screened using labor practices criteria	G4—LA14
	Percentage of new suppliers that were screened using human rights criteria	G4—HR10

(continued)

Table 8.1 (continued)

Sustainability BSC perspective	Sustainability indicators	Source
Learning and Growth	Percentage of total workforce represented in formal joint management –worker health and safety committees that help monitor and advise on occupational health and safety programs	G4—LA5
	Average hours of training per year per employee by gender, and by employee, and by employee category.	G4—LA9
	Total hours of employee training on human rights policies and procedures concerning aspects of human rights that are relevant to including operations including the percentage of employees trained	G4—HR2

8.3.4 Phase 4: Data Collection

It has been widely noted in the literature that data collection has overwhelmingly focused on single firms rather than the supply chain as a whole (Hassini et al. 2012; Seuring 2013; Seuring and Gold 2013). Ahi and Searcy (2015, p. 2890) state that "data availability is a fundamental issue for any model focused on measuring sustainability performance in supply chains". The complexity of including customer/supplier input when measuring across organizational boundaries is also stressed by Hervani et al. (2005).

In the proposed approach, the instrument used for collecting the necessary data for enabling the SBSC for Supply Chain Performance Measurement is a questionnaire to be sent annually to all first-tier suppliers, which will allow the analysis of the evolution of the indicators to be monitored and their comparison with previous years. This option represents a simple and effective way to collect the information necessary to evaluate the sustainability performance of the supply chain to the extent that it can be incorporated into the standard procedures that are presently implemented for supplier evaluation in most of the ISO certified companies.

8.3.5 Phase 5: Data Processing And Implementation, Including Monitoring—PDCA Cycle, and Sensitivity Analysis

The comparison among different suppliers performance cannot be directly assessed. This is because each indicator has different units, not comparable with each other and also because they have different importance. The objective of the proposed methodology is to give directions to separately improve each of the indicators. The analysis of the results for the various indicators, for each of the sustainability scorecard perspectives, is focused on the analysis of each indicator individually.

A spider diagram, as the illustrative example showed in Fig. 8.4, is used for performance measurement. One sophisticated use of the spider diagram methodology is the Arup SPeAR model, which applies the United Kingdom's Government's Sustainable Development Indicators and the Global Reporting Initiative (GRI) indicators within its project appraisal framework.

The follow-up phase for these indicators is carried out jointly by the Purchasing and Environmental Management departments. If there are deviations from the objectives, an action plan should be put into place in accordance with the principles of the continuous improvement cycle, present in the PDCA cycle. Those areas that most negatively impact the sustainability performance of the supply chain for the company can be identified clearly and unequivocally.

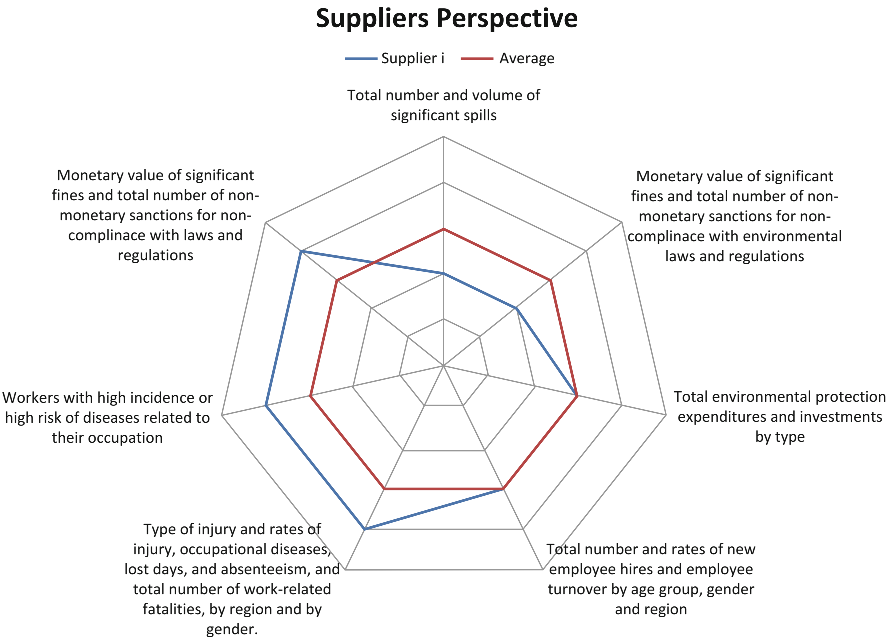

Fig. 8.4 Illustrative example of sustainability indicators for the suppliers perspective

8.4 Conclusions

This paper presents a new sustainability balanced scorecard framework which explicitly considers economical, environmental and social issues indicators to measure the sustainability performance of an upstream supply chain. The evaluation process consists of a model based on the balanced scorecard, integrating the sustainability concerns into all four perspectives. A group of relevant indicators, for each perspective, should be identified taking in account significant aspects of the supply chain in question and the availability of data.

This framework underlines the importance in taking in consideration the unique local context of any particular supply chain into account and is expected to help practitioners in the analysis of trade-offs among economic, environmental and social performance of supply chains, which, could be of use, in developing a business case for sustainability.

One of the difficulties related to the correct application of this model, relies on a deep understanding on the impacts of the supply chain. It can also be noted that the level of complexity of the supply chain can be a determining factor for the successful application of the model, due to the practical difficulties involved in the collaborative development of the strategy map and collecting the necessary data. It may be necessary for the organization under study to have significant influence over its suppliers in order to gain access to the required data.

The exploration of issues related to the implementation of the framework: practical difficulties, resistance from different stakeholders in implementing such frameworks are worth of being explored. To do so, the proposed framework needs to be tested with a set of companies belonging to supply chains of different sizes and complexity.

There are several paths open to the developments of the model. Improvements in the model could include the construction of an aggregate measure, for example an index, to identify which supplier has the best sustainability performance for the supply chain. Furthermore, it would be interesting to consider the possibility to expand the frontiers of the proposed model, including its application to all the upstream and downstream tiers of the supply chain. Obviously, this would imply the ability to collect the required data along the others supply chain tiers, which may be difficult in real world scenarios.

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Chapter 9
Improving Production Flexibility in an Industrial Company by Shortening Changeover Time: A Triple Helix Collaborative Project

Justyna Trojanowska, Krzysztof Żywicki, Maria Leonilde R. Varela, and José Machado

Abstract This chapter presents a triple helix collaborative project carried out through the collaboration of members of three Universities in order to analyze the impact of shortening changeover time on production flexibility in an Industrial Company. The project has been developed for a production company, whose products are fibreboard, hardboard, and soft board products manufactured by a highly specialized Industry using only pure wood fibres. The main reason why it was decided to complete the project was the existence of too long lead times, which meant that many orders were delayed. The main objectives of the project were to reduce changeover times and to increase production flexibility. Therefore, changeover time was analyzed to understand if some activities could be eliminated, moved or simplified. The implemented solution has resulted in shortened lead time, improved workflow, reduced costs of line putting in readiness, standardized changeovers, and has significantly contributed to improving the competitiveness of the Company on the market.

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9.1 Introduction

Economic changes on the competitiveness of wood industry are forcing the producers willing to maintain their position on the market to search for solutions designed to streamline production processes. The development of technique and technology requires changes in manufacturing methods, tools, or organization of production processes. In order to be competitive, modern companies must also quickly respond to changing demand for their products. Therefore, the application of appropriate management concepts or philosophies, aimed at reducing costs and improving production flexibility by eliminating waste and improving production processes are very important. Thereby, obtaining a competitive advantage leads often to the need for applying the Lean Manufacturing Methodology and this is derived from the Toyota Production System concept. Creators of this methodology were Sakichi Toyoda, Ki'ichirō Toyoda, and Taiichi Ohno. The main types of "waste" identified in manufacturing companies are usually divided into seven categories (over-production, inventory, unnecessary movements, unnecessary over-processing, defects, unnecessary transport, and lag) (Wiśniewska and Malinowska 2011) and one of the main tools used to ensure improvements and waste reduction or elimination regarding these categories is the method of Single Minute Exchange of Die (SMED) (Shingo 1985; Womack and Jones 2001). The creator of the SMED methodology is Shingeo Shingo, who introduced the concept of rapid changeovers in 1950.

The first scientific publication indexed in Scopus on the subject of Single Minute Exchange of Die is an article in the area of Industrial Engineering written by Johasen Per and McGuire Kenneth J., and entitled *Lesson in SMED with Shigeo Shingo*, published in 1986 and a conference paper entitled *SMED equals higher productivity*, written by Stickler Michael J. in the same year, and published in the Annual International Conference Proceedings by the American Production and Inventory Control Society. The number of scientific publications indexed in Scopus on the subject of SMED broken down to years is shown in Fig. 9.1.

The issue of SMED is discussed in various scientific fields, but most often in scientific publications in the field of engineering sciences (54% of all publications), and followed by the fields of business, management, and accounting (18% of all publications).

The growing interest in the concept of SMED among scientists over the past years is reflected also in enterprises. Companies are increasingly willing to start improving processes in their companies by implementing SMED. This chapter will discuss the influence of SMED on production flexibility.

9.2 Literature Review

The increasing speed of technological change and the globalization of emerging markets have intensified competition worldwide, leading manufacturers to face unprecedented pressure levels. The tensions created by the emergence of foreign products, the introduction of new products to the market by competitors, more innovative methods,

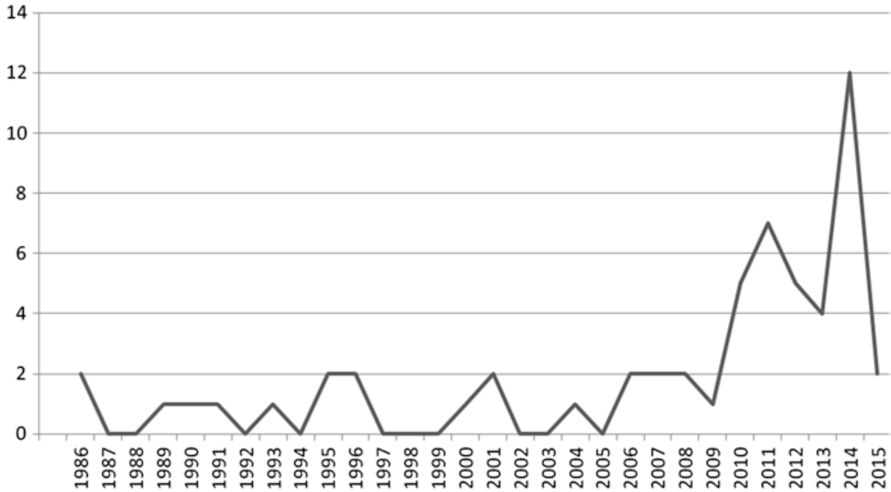

Fig. 9.1 The number of scientific publications on the subject of SMED indexed in Scopus

items with shorter life, and advances in production and information technology have forced companies to respond to these demanding and growing challenges, as stated by Karim Smith et al., in 2008 (Karim et al. 2008). As a result, organizations that understood the importance of belonging to a global market sought to become more competitive through the use of operational methods based on innovative production systems, distinct from traditional manufacturing models, as referred in 2005, by Rawabdeh (2005), which were unable to meet the requirements and paradigms of the current situation. Thus, Companies have been forced to look beyond costs, looking for a greater emphasis on products that are needed by customers, while providing answers more quickly than their competitors, and exceeding quality requirements (Rawabdeh 2005).

According to Womack and Jones, in 2003, in order to achieve these objectives outlined by the organizations it is useful to apply Lean Production (LP) Methodology (Womack and Jones 2003). This concept was introduced by John Krafcik, referred by Womack et al., in 1990, in relation to Toyota Production System (TPS) (Womack et al. 1990). LP was defined by Shah and Ward, in 2003, as a multi-dimensional approach that encompasses a wide variety of tools in an integrated system (Shah and Ward 2003), whose main underlying ideas focus on the continuous elimination of “waste” consisting in all the activities that add no value to the process or products; this new approach requires a fundamental change in the culture of the organization, as stated by Liker, in 2004 (Liker 2004), and Pavnaskar et al., in 2003 (Pavnaskar et al. 2003). As Melton showed in 2005 (Melton 2005), the lean philosophy can l give in to many benefits, such as reduced lead times, reduced need for re-work, reduced costs, increased robustness of processes, reduced inventory, and elimination of “Muda”.

In the well-known book "Toyota Production System: Beyond Large-Scale Production" by Ohno, in 1988 (Ohno 1988), the author identified over-production, defects, excess inventory, drives to overproduce, transport, and lags as the seven "wastes" to be eliminated through the implementation of this methodology. Later, Liker, in 2004 (Liker 2004) pointed to workers' creativity waste as the eighth waste, believing that organizations that do not involve staff or listen to their employees are responsible for loss of time, ideas, and opportunities for improvement and learning.

The Lean Methodology is based on five fundamental principles put forward by Womack and Jones, in 2003 (Womack and Jones 2003)—Value, Value Chain, Flow, Pull and Perfection—which, according to Hines et al., in 2011 (Hines et al. 2011), enable to demonstrate how this approach can be extended to any organization or company, regardless of the kind of industry in which they operate, or the country where they are based in. The value specifies what does actually add value to a certain process or product, according to the customers' perspective, and is the first critical step of this philosophy. Creating a Value Chain ensures that each step provides value by summing up the activities necessary to obtain a product or service that satisfies customer needs. The flow rearranges the processes in order for products to move smoothly throughout the steps of creating value. The Pull Strategy allows the client to "pull" the product, rather than being pushed to him. Finally there is the idea of Perfection, which is based on a constant effort to meet customer needs, to improve processes and achieve "zero defects", as stated by several authors, namely by Womack and Jones, in 2003, and by Staats et al., in 2011 (Womack and Jones 2003; Staats et al. 2011; Salgado and Varela 2010a, b). When implemented together, these principles form the Lean thinking for simplifying how the company produces value for its customers while eliminating all kind of waste, providing an optimal process that, through incremental and gradual changes, can completely change work processes- and mostly—people (Pinto 2008).

The Lean Production Model provides a set of tools that assist in the identification and steady elimination of "Muda" in a company or organization, as shown by Kumar and Abuthakeer, in 2012 (Kumar and Abuthakeer 2012), such as Kaizen (Continuous Improvement), Value Stream Mapping (VSM), 5S, Total Productive Maintenance (TPM), Single Minute Exchange of Die (SMED) and Just-in-Time (JIT). The Kaizen philosophy is the starting point for all Lean initiatives and is based on continuous improvement throughout the organization, as referred by Ortiz, in 2006 (Ortiz 2006). The VSM, as an analysis and diagnostic tool, displays and identifies waste and its sources, as stated by Rother and Shook, in 2003 (Rother and Shook; 2003). In 1997, Courtois et al. stated that the "5Ss" aim at the systematization of the Companies' activities, and at the organization and cleaning of workspaces (Courtois et al. 1997). Moreover, in 2001, Swanson, showed that TPM seeks to improve the performance of the equipment while constantly preventing the occurrence of faults (Swanson 2001).

According to the principle of Lean Manufacturing production, a system should produce only as many products as customers order.

The objective of production levelling is to balance production volume as well as production mix by decoupling production orders and customer demand (Liker 2004). Thus, work load in production and logistic processes are balanced. Conventional levelling approaches aim at distributing production volume and mix to equable short periods (Huttmeir et al. 2009). The sequence of these periods describes a kind of manufacturing frequency. According to this levelling pattern, every product type is manufactured within a periodic interval, for example a day, or a shift (Lippolt and Furmans 2008). The duration of this interval is depicted by the key figure EPEI (“every part every interval”). The EPEI-value is used as an index for reactivity and it also reflects lot sizes (Rother and Harris 2001).

If the production of all items assigned to a machine takes 2 days, EPEI comes to 2 days. This means that a lot size should correspond to the customer’s 2-day demand for the product family. EPEI reflects how often a process can produce items from the entire product range. In a wider interpretation of EPEI, it can be said that it reflects the flexibility of the production process (the pace of WIP inventory replenishment; the rotation aspect) (Domański et al. 2012). The EPEI index for an object is calculated as follows (Hamel 2010):

$$EPEI = \frac{\sum_{i=1}^{j} T_{\Delta i}}{T_{a\Delta}}$$

Where:

EPEI—the fixed “every part every interval” over a prescribed interval period,

j—the number of different parts that are produced/processed on the given machine,

$T_{a\Delta}$	—internal changeover time, typically minutes, for each part, on a given machine
$T_{\Delta i}$	—available time, typically minutes, for changeovers per period, typically a day, or shift, on a given machine

The SMED allows a decrease of equipment setup times, providing many benefits to Companies, such as reductions in stock levels, WIP, size of the lots, times of production and delays, as well as improvements in quality, flexibility of production, safety, and capacity, as stated by Shingo, in 1985 (Shingo 1985). Moreover, according to Courtois et al., in 1997 (Courtois et al. 1997), the JIT philosophy aims to produce only what will be sold at the time when needed, attempting to eliminate as much waste as possible in organizations, in order to achieve zero inventory, as also referred by Ha and Kim, in 1997 (Ha and Kim 1997). However, Liker, in 2004 (Liker 2004) recalls that the use of Lean tools in a Company is not in itself a guarantee of success, since the possibility of adopting this philosophy, as a competitive and sustainable advantage, is dependent on observing all its principles. When this is not accurately accomplished, companies are only able to generate short-term results and will turn unsustainable.

9.3 Single Minute Exchange of Die

The SMED method is a fast changing tool aiming at reducing the time of production changeover. This method does also facilitate the reduction of waste by setting the minimal lot size.

During the production changeover, there is an important aspect of production that should not be neglected: the fabrication line starting process. This part could represent a significant time waste if it is not performed well. The objective is to reduce setting time, in order to decrease the production changeover time or instant adjustments. Hence, in order to reduce the setting time of the production changeover, two major procedures may be adopted (Shingo 1985):

- Internal operations: i.e. operations that can be performed only during machine time down, and with no load;
- External operations: operations that can be performed only during machine time up/during production mode.

In order to apply this technique, four steps must be followed strictly (Kumar and Suresh 2008):

1. *Identification of Internal and External Operations*

This first step will affect the result if it is not done well. In classic settings, internal and external operations are mixed. It means that some internal operations are done in external way, and vice versa. A precise analysis on how its production changeover is done, at a given moment, should be undertaken. One way to accomplish this step is to film one or more production changeover. Those films will be analyzed by a group of workers or technicians. It is necessary to identify each operation in the production changeover. There are 12 distinct operations—preparation, settings, test, fixing, rectification, over-production, displacement, transport, waiting, stocks, operation, and staff use.

2. Internal and External Operation Separation

This is probably the most important step in the SMED process. In fact, the more operations are separated from one type to the other, the easier it will be to eliminate waste time. This is why this step needs to be performed by a group of various persons.

3. *Internal to External Transformation*

Mostly, everyone wants to perform as many tasks as possible in external settings. In fact, external settings can be realized even if the machine is in production mode. External times can be minimized in so far as the worker could prepare everything for the next production changeover.

4. *Settings Tasks Rationalization*

The last steps of the SMED Method consist in minimizing settings time. The conversion of internal settings to external settings generates a time gain. However, when we rationalize settings, we could improve the minimization of the production changeover time.

Of course, it is necessary to maintain the time that has been defined in the final standard. That is why results should be recorded in a graph. Each time that the time limit is reached or exceeded the staff has to check for the main cause. This way, time goals can be established.

Successful implementation of SMED will maintain the stability of the production process, thus enhancing the flexibility and making it possible to shorten lead time.

9.4 Industrial Study

Tests were carried out in a wood manufacturing Company where one of the main products was porous fibreboards. The research was conducted at the department of surface coating. The analyzed section performed the following operations: bonding, grinding, profile-based panels cutting, and milling plate edges. The type of cutter used in the milling operation was dependent on the product currently being produced.

The diagram of the process is shown in Fig. 9.2.

In the analyzed Company, employees work following a four-brigade system. On the line where the research was conducted there is one operator for the milling machine, one operator for the gluing line and there are two assistant operators. In addition, in the department there are also a master and a foreman who participate in the process of changeover. The tasks of operators are:

- loading semi-finished products on the line,
- controlling glue dispensing,
- collecting plates,
- performing quality control,
- ensuring machine changeover,
- performing line maintenance at a standstill.

A. *Analysis of the Changeover Process*

In order to carry on with the study, on-site data were collected (Table 9.1), and the EPEI index was calculated.

Before measuring changeover time, all changeover activities are divided into two categories:

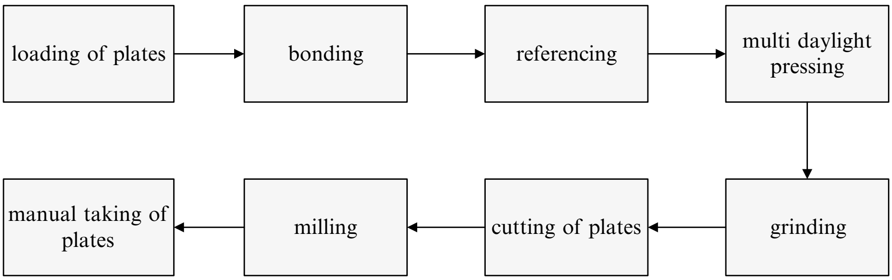

Fig. 9.2 Production process diagram

Table 9.1 EPEI index

Number of possible changeovers—on a 7 days basis					
		Product lot			Total
		A	B	C	
Average product demand during the given period	items	23,618	7668	4288	35,574
Cycle time	sec	11	18	25	54
Lead time for demand	min	4330	2300	1787	8417
Uptime during the given period	min	10,080			10,080
Scheduled breaks	min	0			0
Productivity	%	65			65
Effective time	min	6552			6552
Time available for changeover	min				1865
Average changeover time	min	95			95
Possible number of changeovers during the given period	items				20
EPEI index		5.6			

- C1—change in machine settings involving the change in the dimensions of the plate and adjustment of the position of the elements involved in the changeover;
- C2—change in machine and cutter settings involving the adjustment of the position of the elements involved in the changeover, and replacing the cutter.

During the month this research took place there were a total of 39 changeovers, with a total time of 3699 min. More detailed information regarding the changeovers is summarized in Table 9.2.

Changeovers performed by operators were recorded on video camera, and then all the films were analyzed for changeover process improvement opportunities. The analysis of the current situation revealed a number of factors negatively affecting changeovers times, which can be grouped into the following main classes: method, material, machine, man, and environment, including factors such as: lack of work standards, lack of tools, lack of maintenance, failure to follow processing instructions, lack of automation, and obsolete machinery, along with lack of motivation, and adequate competence of operators. These kind of main sources of irregularities are presented in the form of the Ishikawa diagram depicted in Fig. 9.3.

A thorough analysis of the Ishikawa diagram indicated that the most important factors affecting the long changeover times are mainly due to:

- the fact that operators performing changeovers have not been trained, and therefore performing various actions takes a long time, thus operators do not know the costs they generate by long changeovers.
- lack of motivation and lack of communication between operators.
- the fact that information about products to be produced for a next order is delivered late to operators.

Table 9.2 Changeovers information

Type of changeover	C1	C2
Number of changeovers	19	20
The average time of one changeover	61 min	127 min

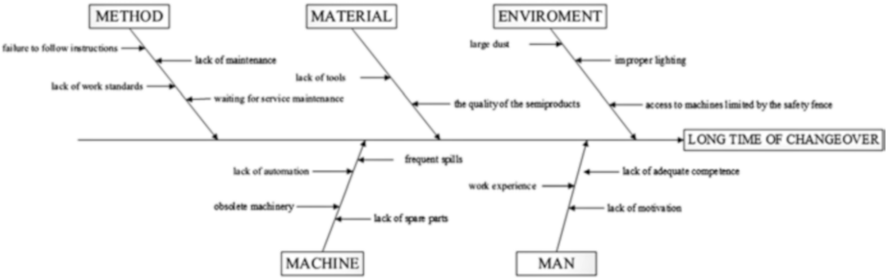

Fig. 9.3 Ishikawa diagram

- the fact that the tools are stored too far from the machine and they are in disarray. The lack of standards when it comes to storing individual mills, as well as the lack of order among necessary tools is also visible, as operators use other tools, thus the extension of the changeover process.
- Upon a more particular analysis, factors affecting the duration of changeover time were identified. They are mainly related to the lack of work standards, obsolete machinery and lack of operator training. The critical factors were indicated using Pareto Analysis shown in Fig. 9.4 and summarized in Table 9.3.

For each critical factor the causes were identified. The results are summarized in Table 3.

A timetable for the implementation of the new solutions was formulated and employees were informed about plans aiming to introduce changes in the changeover process.

B. *Shortening Changeover Time*

In an effort to increase production flexibility, shadow boards, toolboxes and tools that had been cleaned up were introduced in workplaces. Also, visual storage standards for cutters were introduces, along with a number of changes in the spatial display of objects (Fig. 9.5).

Minor design changes were introduced to improve the changing the instrumentation on the lines.

Examples of changes made in the analyzed area are shown in Table 9.4, which presents an outline of the main changes that were introduced in the factory and the underlying manufacturing processes, and which have led to a general improvement

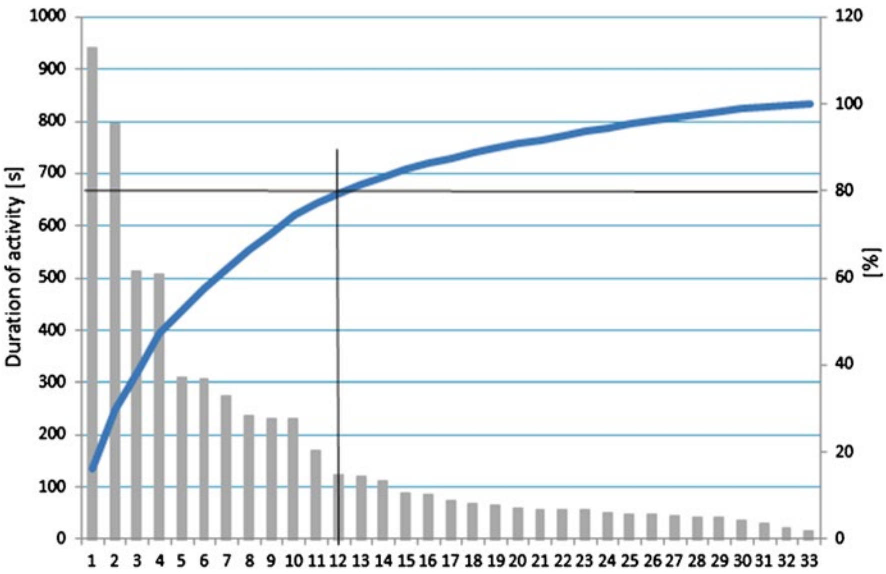

Fig. 9.4 Pareto analysis

Table 9.3 Critical factors

No	Critical factors	Causes
1	Toaster settings correction	Toaster construction sealing
2	Cutter insert change	Lack of cutter standardization
3	Milling settings correction	Wrong initial setting
4	Removing cutters	Wedged cutters
5	Fibreboard control measurements	Incorrect initial production line setting
6	Cutter assembly	Complicated assembly—lack of operator training
7	Idle motion of milling	Slow machine functioning
8	Transfer of cutters behind milling longitudinal	Tools are not prepared accordingly before changeover
9	Cutter guard set up	Lack of an adequate number of tools
10	Idle motion of crawler track	Lack of proper tools
11	Air hoses removal	Lack of proper tools
12	Settings correction on fibre board tray loading	Mistakes made by operator

of the whole production environment and processes. These improvements were mainly related to the introduction of alternative changeover scenarios, along with training sessions for operators, and a set of activities for enabling the preparation of materials and cutters before production.

Fig. 9.5 Cutter's storage booth

Table 9.4 Design changes on the lines

	
Crank with a long shoulder, ensuring high speed operation and requiring less operator strength	Compressed air hoses facilitating slot purification
	
Modified safety fence ensuring safety without inhibiting the access to milling machines	Stopper which prevents cutter displacement
	
Scale which helps reducing manual time measurement	Mounting folding covers, and avoiding dirt and clogging and the displacement of the mill while working

Table 9.5 EPEI index after improvement

Number of possible changeovers—on a 7 days basis							
		Product lot					Total
		A	B	C	D	E	
Average product demand during the given period	Items	18,577	14,293	3788	154	112	36,924
Cycle time	sec	7	13	47	6	11	84
Lead time for demand	min	2167	3097	2967	15	21	8267
Uptime during the given period	min	10,080					10,080
Scheduled breaks	min	0					0
Productivity	%	66					66
Effective time	min	6652.8					6652.8
Time available for changeover	min						1615
Average changeover time	min	35					35
Possible number of changeovers during the given period	items						46
EPEI index		3.93					

Thus, summarizing, the main improvements introduced were related to the introduction of scenarios for shorter changeovers and for improved machine maintenance. Moreover, all operators were trained, and external activities like the preparation of cutters and their delivery to the workstation were performed before stopping the line.

The activities performed have had a positive effect on the EPEI index that in relation to the initial value has decreased by 30% (see Table 9.5).

9.5 Conclusions

Implementing the SMED method has lead to a decrease in changeover time by 50%. This effect translates into increased production flexibility, which shows the decrease in the index value EPEI by 30%. The Company has introduced a monthly monitoring of changeovers and SMED trainings for operators which are held once a quarter. The analysis of the achievements over three months subsequent to the completion of the project indicated a further decrease in changeover times and an increase in production flexibility manifested by a higher number of changeovers. Standardization of changeovers has caused reduction of the cost of line putting in readiness. This project has also had a positive impact on lead time which is now shorter. Actions taken during this project have resulted in an increase in the Company's competitiveness on the market, by enabling a quicker and better answer to the demands of the clients.

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Chapter 10
Sectoral Systems of Innovation and Nanotechnology: Challenges Ahead

António Carrizo Moreira and Alexandra Alves Vale

Abstract Nanotechnology has emerged as a revolution and is one of the major research initiatives of the 21st century. Several industries are involved in nanotechnology research and invest heavily in R&D in order to create brand new products with functions never imagined before. Breakthrough technologies are expected to change the competitive landscape, across several industries, completely. As there are several scenarios analyzing the future outlook of nanotechnology, as well as how it has been developed in several countries, the aim of this chapter is to analyze nanotechnology from a sectoral innovation perspective and to advance the necessary conditions to implement it.

10.1 Introduction

Nowadays, businesses operate in a very dynamic, uncertain and competitive environment, and try to achieve a competitive advantage in order to obtain a stable market position. As newness attracts new clients, the best way for firms to achieve a competitive advantage is through innovation. According to Fagerberg et al. (2004), innovation has become a factor of development and success for companies and countries, paving the way to economic growth and thus, achieving a leadership position in a specific field for innovative nations. This indicates that producing efficiently is not enough. It is necessary to introduce new features, improvements, or entirely new features *vis-à-vis* existing products (Fagerberg et al. 2004). Innovating involves generating, developing and establishing new ideas or procedures (Dantas and Moreira 2011). As a result, we may have new products or services, new technologies and new administrative structures and systems. Therefore, innovation is the viable alternative for implementing changes in the organization, either to respond to changes in internal or external environments or as an active strategy to

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overcome competitors. Technological advances have underpinned countries, as well as firms, to introduce innovation in economic activity. Every technological innovation affects both the society and the environment. As the world is completely wrapped in technology competition, the evolution of mankind is completely dependent on technology (Gerguri et al. 2013; Lo 2015).

Innovation systems can be defined as a group of private businesses, public research institutes and several innovation facilitators that, by interacting among themselves, can promote the creation and facilitate the diffusion or application of a series of technological innovations (Malerba 2002; Gambardella and McGahan 2010; Beige 1998).

In general, a system of innovation is constituted by its components and the relationships among them. The main constituents of an innovation system are: organizations and institutions. The former are represented by formal structures that are consciously created and have an explicit purpose; they are defined as actors. The latter are sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations; these can be regarded as the rules of the game (Freeman 1987; Malerba 2002; Moreira et al. 2008).

According to the system of innovation theory, the key for innovation and technology development is represented by the transfer of knowledge and information among all the actors involved. Moreover, innovation systems can be used to analyze industries from a different perspective not dealt with by the old theories of technological change (Freeman 1987; Moreira et al. 2007; Albuquerque et al. 2012).

Edquist (1997) put forward a more general definition proposing that an innovation system is the group of all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion and use of innovations.

Innovation and innovation systems are becoming increasingly important for policymakers to achieve their economic and social goals. The “Europe 2020” strategy, a key European Union (EU) program for the current decade, aims to promote a smart, sustainable and inclusive economy. According to the European Commission (2011), innovation has to be placed in the center of the strategy, as it provides the best ways to successfully address key social challenges.

An efficient framework based on connections between all the actors is the key to succeed in achieving innovation and it is represented by the design of a strategic system of innovation.

The notion that certain industries have different needs and technological trajectories was first proposed by Pavitt (1984) who developed a taxonomy about sectoral patterns of innovation according to the sources of technology, user needs and the technology appropriability regimes: supplier dominated sector; scale intensive sector; specialized suppliers and science-based sectors.

Sectoral systems are prone to changes which could be caused by technology, by learning/knowledge practices of the industry, as well as by innovation patterns of the businesses and industries. A change in the knowledge base can lead to consolidation or to significant changes within the industry if a new dominant design brings new results (for example, the iPhone is a clear case of how a dominant design changed competition and industry patterns). Another source of change is the consumer demand structure, which can lead new companies to enter the industry and change it considerably. Generally, these dynamics follow a co-evolutionary nature, leading to changes in terms of technology, knowledge, players and institutions (Pavitt 1984; Freeman 1987; Gambardella and McGahan 2010).

The concept of sectoral systems of innovation (SSI) was developed by Malerba (2002), who claims that a SSI is a set of new and established products developed for a special purpose by a set of agents. Those agents carry out activities and market interactions for the creation, production and sale of these products. Malerba (2002) describes an SSI through three dimensions that are responsible for generating innovation and new technologies: knowledge and technological expertise, players and chains, and institutions. These three dimensions are the main pillars of the concept of sectoral systems of innovation as a result of the interaction of various functional logics, complexity and dynamism which are a result of the generation and diffusion of innovation (Malerba 2002).

In the first dimension, one key issue that is worth mentioning is the focus on knowledge that drives the mastery of a technology as well as the dynamic complementarities and linkages that are the main sources of transformation and growth of sectoral systems, leading towards innovation and change. In the second dimension, an industry is composed of individuals and organizations (agents) at various levels of aggregation with specific learning processes, skills, organizational structure, beliefs, goals and behaviors that interact through communication, exchanges, cooperation and competitive processes. Consequently, heterogeneous structures are formed so that their interactions can enable the exchange of knowledge that generates innovation. Lastly, institutions are a composite of norms, routines, common habits, established practices, rules, laws, and standards that shape the interactions among agents.

Dosi et al. (1988) highlighted three features that have influenced the emergence of new technologies: (a) *the knowledge of a technology*, which shapes and constrains the evolution and subsequent rates of technological change, regardless of the market; (b) the stabilization of *the pattern of technical change,* and (c) the *technical change* that is partially influenced by technological changes created within the evolutionary path, which creates an imbalance for new technological changes.

Edquist (1997) has introduced the concept of *innovation systems* based on the following features:

- The innovation, intrinsically connected to learning;
- A holistic and interdisciplinary perspective, involving institutional, organizational, social and political determinants;
- A path-dependent historical perspective;
- An emphasis on the interdependence and non-linearity of the innovation process;
- The main role given to institutions.

The importance of innovation systems stems from the interaction among actors. Heidenreich (2004) argues that the trust-based patterns of cooperation, the local experience-based, context-bound knowledge and the path dependent accumulation of competencies are crucial for an innovation system to prosper. Heidenreich (2004) has also found that the governance structure of an innovation system may, to some degree, limit the innovation process of the region.

Following this systemic approach, the links between businesses and other organizations are portrayed as the result of the technological interdependence of their knowledge (Chang and Chen 2004; Moreira et al. 2007).

Innovation is an interactive process that has the contribution of various economic and social agents, which are characterized by different types of information and knowledge. It can be classified into two categories: incremental and radical (Dantas and Moreira 2011; Fagerberg et al. 2004). The radical innovation emerges when a new product, process or even new organizational solution is developed or introduced onto the market. This type of innovation leads to the destruction of the old technology standards, leading to new industries, sectors and markets that change the economic environment. Incremental innovation may emerge from practice and continuous improvement (Dantas and Moreira 2011).

The impact of innovation on economic growth is not new. Schumpeter (1943) states that economic development and the diffusion of radical innovations are linked with the creative destruction process, which leads to changes in the pace of economic growth and in the production structure.

Schumpeter's (1943) contribution demonstrates that the economic disruption follows when sectors and technologies become obsolete and unprofitable and new industries and technologies make it possible to behave monopolistically, thus creating the creative wave, where there are two points of view for the same process, innovation being the economic transformation agent. Clearly, nanotechnologies will help to make certain technologies obsolete and will generate the Schumpeterian creative destruction process. For countries with scarce natural resources, the need for a strong focus on continuous innovation to achieve the expected international competitiveness level is clear (Souza and Câmara 2009). Human capital and knowledge are two particularly important components of this creative destruction process as it is vital to establish the basis for new technological progress. The theory of endogenous growth has been followed by a controversial debate about the origins of technological progress and its implications on sustainable growth (Ott et al. 2009). However, regardless of the circumstances, nanotechnology will have important social and economic effects (Foley and Wiek 2014; Schulte 2005; Motoyama and Eisler 2011).

Emerging technologies are very important as they underpin the opening up of new markets and pave the way for increased competitiveness of the industry with significant consequences for both public and private sectors (Koh and Wong 2005; Moreira et al. 2007; Moreira et al. 2008).

Nanotechnologies are not only a vivid example of emerging technologies (Bachmann et al. 2001), but also of the pervasive consequences for the societal consequences as there are clear intersections among nanotechnologies, biotechnologies and information technologies (Fleischer et al. 2005). Smadja (2006) states very clearly that there are four possible scenarios involving the levels of nanoscience and nanotechnologies: (a) *undesired*, in which nanotechnology is socially accepted and embraced, yet with an uncertain future; (b) *more of the same*, in which nanotechnology is widespread but involves a very simple technological evolution; (c) nanotechnology is *not accepted*; and (d) *unfulfilled promises*, in which a breakthrough never occurs. Karaca and Öner (2015) found five possible scenarios: (a) *nano-averse*, where no single nanotechnology product is marketed; (b) *go-nano*, the best possible case, where a range of products is expected to be marketed before 2020; (c) *limited nano*, although with the same potential as the go-nano scenario, there are very few nanoproducts that will go to the market before 2020; (d) *low-nano*, in which neither the public nor the private sector is willing to invest in nanotechnologies; (e) *incapable to nano*, in which no product reaches the market.

The objective of this chapter is to show how different nations approached the generation of a national system of innovation for nanotechnologies and to explore the importance of the systemic perspective for the development and growth of nanotechnology innovation.

The chapter is structured into seven sections. After this introduction, the second section briefly refers to the methodology used. The third section addresses nanotechnology. The fourth section addresses nanotech sectoral systems. Section 10.5 presents the structure and evaluation of innovation systems. The sixth section presents a comparative perspective of nanotechnology among several countries. Finally, conclusions are drawn in Sect. 10.7.

10.2 Methodology

The methodology of this chapter was based on a review of existing literature on sectoral systems of innovation involving nanotechnology related studies.

In particular, the cases of the USA, Germany, Sweden, Russia, Iran and South Korea will be described. Information about the way they have approached the innovation system and the generation of strategic plans will be analyzed, taking into account the main features of nanotechnology on a sectoral innovation perspective. Reports on national analyses were also accounted for when writing this chapter.

Indeed companies and countries should be aware that investment in R&D, particularly with regard to nanotechnology and nanoscience is an asset to the long-term success of industries and nations.

10.3 Nanotechnology

In a world where information and communications technologies have pervasive effects across several industries, nanotechnology stands out for its application in various research fields and in almost all scientific disciplines (Islam and Miyazaki 2009; Nikulainen and Palmberg 2010).

Nanotechnology emerged in the 1960s, when its concept was introduced by Richard P. Feynman, Nobel Prize in physics in 1965, the pioneer in the field of quantum computing. Nanotechnology is mentioned as a set of emerging tools that enables us to generate and manipulate materials and structures at molecular and atomic level. As nanotechnologies, one can consider the technologies with structures between one and a thousand nanometers (Schulte 2005). One cannot forget that science is capable of creating new products and tools at high speed in our daily lives, and the term encompasses different non-specific technologies, which are extensively described in various technical documents that show great potential for incremental and innovative applications (European Commission 2011; Kostoff et al. 2007; Allarakhia and Walsh 2012).

Nanotechnology comes as a worldwide revolution and is the first major research initiative of the 21st century (Marques 2008; Gkanas et al. 2013). Many authors believe that, in the future, nanotechnology will dominate generic technologies (Ott et al. 2009).

The brand new properties that nanostructured materials present, make scientists believe that nanotechnology may represent the answer for the development and production of components potentially able to benefit society. In fact, those materials may find application in numerous fields such as health, electronics, energy saving and production, automotive industry, pollution treatment and environmental industry (Miyazaki and Islam 2007; Islam and Miyazaki 2009; Zhao et al. 2003).

Nanotechnology comes as a revolution in the world and is the first major research initiative of the eleventh century worldwide. Several industries have heavily invested in R&D to create products with unimagined functions. This new technology has changed the competitive conditions in many sectors of the economy (Marques 2008; Gkanas et al. 2013). It mirrors a new dimension of solving problems by creating brand new solutions and driving new technological developments with strong impact on the wealth of humanity. This wealth is subject to the realm of new opportunities that are emerging through research based on micro systems technology (Souza and Câmara 2009).

The pervasive effects of nanotechnology are quite widespread and incorporated into production lines or in products developed for several industries, such as energy, health, pharmacy, water, petrochemical, agribusiness, electronics, fine chemicals, military, aerospace, automotive, among others (Islam and Miyazaki 2009; Allarakhia and Walsh 2012; Maine et al. 2014). Having a strong economic and social future potential to meet global challenges, nanotechnology has been considered the basis of the next industrial revolution (ObservatoryNANO, 2011).

Nanotechnology-related innovations may be of added value to the environment. For instance, in the production of clean energy, it is expected that the nano-wires and nano structured materials can create cheaper and more efficient solar cells. Nanotechnology may also lead to higher energy content batteries and enable manufacturers to improve the environmental performance of products, allowing them to reduce toxicity, increase durability and improve energy performance (European Commission 2011).

Economy-wise, the importance of nanoscience is growing as a result of enhanced labor and technology productivity. As nanoscience and nanotechnology might radically transform the economy environment, developed countries stimulate and apply many resources in these areas in order not to lose their position to other countries with more innovative technology (Andersen 2006). This is a result of the neoschumpeterian theory emphasizing the link between economic and technological development and discontinuity generated by radical innovations.

In order to highlight the opportunities that innovations in nanotechnology can bring to the economy, in the recent Government Accountability Office report (GAO 2014), many industry experts, government and academia expressed that those opportunities could exceed the economic and social impact the digital revolution had on society. The market for nanomedicine alone, for example, was estimated at about 20–40 % of the global nanotechnology market, valued at 78,540 million dollars in 2012, with a growth forecast of 117.60 billion in 2019, according to a new market report published by Transparency Market Research (2014). Various social benefits are also facilitated by nanotechnological innovations. For instance, there are several pilot projects using nanometal particles to remove chemical and biological contaminants from water in rural and underdeveloped regions of the world (Kaiser et al. 2014).

Today's market nanoproducts have been improved gradually in order to better meet the consumers' needs based on the evolutionary nanotechnology pull. Based on its importance in all economic areas (from agriculture to medicine), the number of companies that manufacture nanoproducts will grow exponentially, seeking to improve existing products by creating smaller components with more effective performances, at a lower cost. This evolutionary nanotechnology should therefore be seen as a process that will gradually affect most businesses and industries, with enormous social and economic consequences. Innovations might take place involving the increase in miniaturization of the development of whole new products, processes or services. Innovations in the field of nanotechnology not only affect productivity in downstream supply chain, but can also induce continuous innovation circles (Ott et al. 2009).

10.4 Nanotec Sectoral Systems

Academics agree that the heart of most government policies is the achievement of growth through innovation and technological development. At the same time, nanotechnology is seen by many national and international stakeholders as a fast growing area that can affect and improve technologies in different sectors (Flament 2013).

Islam and Miyazaki (2009) and Schulte (2005) claim that nanoscience is very difficult to follow as it is not a discrete field but has pervasive influences across different lines of scientific disciplines and crosses several industries. However, one common characteristic of nanotechnology is the size of the materials being developed and used, which characterizes nanotechnology as a common technology with super-functional properties at nano-scale for several technology sectors (Bresnahan and Tajtenberg 1995; Islam and Miyazaki 2009). As a result of this specificity, Islam and Miyazaki (2009) analyze the nanotechnological system based on the relationship of four different poles: finance, science, technology and market.

There are great expectations regarding the potentialities of nanotechnology leading various governments to invest billions of dollars in its development. Particularly since 1990s, around 30 countries have designed strategies and created policy initiatives for the development of nanotechnologies (Perez and Sandgren 2008). These initiatives are categorized in what is called a system of innovation, which can be defined as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies (Freeman 1987).

Newness provoked by nanotechnology, as it is in an emerging stage, is probably the hardest difficulty that policy makers usually face when planning an innovation system. In fact, as nanotechnology is a relatively "young" branch of science, there are still many unsolved uncertainties and ambiguities related to how scientific knowledge will lead to the potential application of some nanostructured products. Those aspects make the development of a nanotechnology innovation system a very challenging task.

As a result of the controversial nature of this technology, the consumers' attitude towards the risk may really affect the demand, which can either stimulate or hinder innovation (Ott et al. 2009).

In 2006, William K. Reilly, a former administrator of the US Environmental Protection Agency, with reference to the report on Managing the Effects of Nanotechnology, claimed that nanotechnology can only flourish if industry and government are committed to identifying and managing the possible risks of this technology for workers, consumers and the environment alike. There must be a dialogue between business, government and citizens on how to move forward and develop this technology (Davies 2006). This is a clear indication of the challenging task ahead.

Davies (2006) also admits that reaching a consensus on the regulation of nanotechnology, which encourages economic innovation and environmental management, will not be easy, but it is a challenge we cannot ignore, involving public participation, foresight capability, international harmonization, regulatory incentives, tax breaks and research and innovation programs (Davies 2006). These regulatory issues are extremely important to provide security for businesses, investment and even to convince shareholders of the opportunities of this new industrial platform.

The German Federal Environment Agency (UBA) published a document (Hermann et al., 2014) stating that, based on the uncertainties regarding the assessment of the possible risks, nanomaterials can trigger certain risks on human health and on the environment. The Agency supports, as a preventive measure, the establishment of a European registration support entity for nanomaterials-based products. The creation of this registry is intended to provide a general overview of the products that are in the manufacturing process or already in the market. According to Hermann et al. (2014), this measure would allow public authorities to delimit the priorities for implementation and monitoring, to determine the exposure to humans and to the environment and, in the case of adverse effects, to guarantee the screening. According to Hermann et al. (2014), this measure will take place in a centralized way in the European Union in order to avoid a product from a certain country overriding the EU legislation, meaning not only loss of control of the process, but also an increase of costs for the authorities.

In March 2014, the European Chemicals Agency published a report stating that the requirements applied to the registration of nanomaterials are the same as any other chemical product (Hankin and Caballero 2014), which gives a clear indication that the situation is far from solved.

The perception of the territorial character of the innovation and production has led to the formulation and implementation of policies for the development of local arrangements of production and innovation systems. Paradoxically, with a few exceptions, policies aimed at production have been designed without any regard for the territory (Cook and Memedovic 2003).

Both the OECD countries and the emerging economies seek new ways of implementing green innovation in order to increase their competitiveness, based on the application of new technology (OECD 2013). Nanotechnology attracts a particular attention within the group of new technologies (OECD 2013).

As nanostructures have constituted the driving force that has led to the emergence of new materials for the twenty-first century industries, nanotechnologies are of fundamental interest to the disruption capability that may affect the production sector. According to the Brazilian Agency for Industrial Development (2011), another aspect to consider is the configuration of economic activity in nanotechnology, whose prediction for 2015, according to new economic analysis, a worldwide market, is of about \$3.1 billion for products based on nanomaterials.

10.5 Structure and Evaluation of Innovation Systems

To create a national nanotechnology system of innovation it is important to first identify partners among the scientific community, the business world and government institutions. As seen before, the realization of a system of innovation depends on the interrelations between all actors involved.

In order to create a systemic perspective, it is important to establish centers of competence in specific subjects and network them in clusters. This allows for the assessing of the implications of nanotechnology on health, environment and economy, and for fostering public information campaigns. Several technology management activities can be divided into four types of activities (Zweck et al. 2008; Zhao et al. 2003; Allarakhia and Walsh 2012):

- technological forecasting (both general and for specific innovation fields);
- market assessment and applications;
- innovation and technology analysis;
- communication.

Technological forecasting consists in the continuous monitoring of technological developments leading to an early identification of promising future applications and to an assessment of their potentials with literature and patent analyses, expert surveys, interviews, and questionnaires. The aim is to provide a global view of the technology, its prospects for possible applications and their related deficits, impediments, and recommendations.

This is very important for keeping strong connections among all of the actors.

Market assessment and applications involves the systematic analysis of possible markets and applications for nanotechnology. Market surveys combined with market studies, patent analyses, and interviews with scientists and technology suppliers are important mechanisms of market assessment (Zweck et al. 2008). It is important to have a broad view of market assessment. As such, the economic potential needs to be assessed in some of the most important leading markets.

As experienced in Germany, technology analysis was carried out to investigate and weigh the positive and negative effects of new technologies on society, the economy, and the environment with the aim of using the opportunities they offer while minimizing the hazards (Zweck et al. 2008). This concept might use a broad range of qualitative and quantitative methods to foresee potential risks and technologies in the development process of a new technology as early as possible.

Communication involves public discussion by means of newspapers and televisions in order to give as much information as possible about nanotechnology to people.

As can be seen, the four components are very important for keeping a strong interconnectedness among all stakeholders of the innovation system (Zweck et al. 2008). Each of the mentioned activities represents a particular phase in the evolution of the innovation system. All of the phases are strictly related to each other and in some cases they overlap. The timing of their execution is important for the achievement of the final goal of the innovation system.

As such, it is clear why nanotechnology is considered a future emerging technology and why scientific world publications related to this multidisciplinary field grew exponentially during the last two decades (Miyazaki and Islam 2007; Kostoff et al. 2007; Motoyama and Eisler 2007).

In fact, the lack of investment in research reduces the level of security when launching a new product on the market. This is often associated with dangerous products being widespread in the market. These can be so bad that incredibly good products are not launched on the market due to a lack of certainty regarding their risks (Schulz 2009).

The number of patent applications can be seen as a well-known and valuable indicator for evaluating trends and developments in this area. Patenting is driven by commercial interests and focuses mainly on assessing economic potential. Statistical analyses on nanotechnology related patent activities are of increasing interest to many researchers as they allow for a close follow up of what is occurring worldwide. With the introduction of specific systems of nanotechnology classification such as The United States Patent Trademark Office (USPTO), the Japan Patent Office (JPO) and the European Patent Office (EPO), the ObservatoryNANO (2011) is a base for in-depth analysis of the patenting activities.

10.6 Comparative Perspective

It is not by chance that the discourse on nanotechnology is prevalent in the United States of America (USA). Early in the 1990s several pushes emerged on nanotechnology in the USA. This is a period characterized by a scientific policy increasingly emphasized and supported by the government and where the belief in basic science is seen as the leading economic engine of the USA (National Science and Technology Council 2011).

The strategic plan, entitled the National Nanotechnology Initiative (NNI) had, as its main function, the coordination of goals, priorities and strategies between federal agencies as well as the promotion of interdisciplinary research and critical development of the infrastructure needed for this important technology.

Its initial structure was represented by eight federal agencies that grew to a set of 25 in ten years of program. These agencies implemented nanotechnology related activities in different degrees and were responsible for a series of research papers and regulatory responsibilities that led to the implementation of similar assumptions in several other countries (National Science and Technology Council 2011; Mowery 2011).

Meanwhile, in Russia, SSI involving nanotechnology emerged as a result of actions taken by public authorities. It is important to take into account that government actions over several decades were focused mainly on supporting sectoral systems and scientific infrastructures for development (Gaponenko 2007).

In Iran, the need for developing this technology was also considered by the authorities about a decade ago. The beginning of the research on nanotechnology has led to the formation of the Nanotechnology Development Special Committee (NDSC), which develops and launches 10-year development plans for the development of nanotechnology (Mohammadi et al. 2012).

Germany is one of the leading nations of the nanotechnology industry in Europe. This country has shown interest in this emerging technology since the beginning of the 1990s when the German Ministry of Education and Research (BMBF) recognized this area as a promising field of innovation (Zweck et al. 2008).

The Swedish government also recognized nanotechnology as a field with industrial potential and strategic importance in the long run. However, Sweden has failed to articulate a coordinated national strategy to strengthen the research and development activities in nanotechnology. Only in 2006 did the Royal Swedish Academy of Engineering Sciences presented a plan for a national innovation system involving nanotechnology, influenced by the presentation of a European Commission communication entitled “Towards a European nanotechnology strategy.” This communication stressed the need for interdisciplinary procedures, the intensification and coordination of research at national and European level, the need for building a world-class R&D infrastructure, the need for basic and continuous training of human capital and the development of marketing capabilities by means of appropriate standards and intellectual property rights structures (Perez and Sandgren 2008).

In Asia, South Korea stands out as the leader of research and technological development in nanotechnology. The main feature of the South Korean approach in building a national innovation system is represented by the change of vision of this country in this area. This is because, until 1990, its position before nanotechnology was limited to the knowledge and imitation of foreign technologies. Only around the beginning of the century did the government decide to change its strategy toward an active innovation approach (Song et al. 2007).

Clearly, several nations have set their own innovation system in order to promote the growth of nanotechnology. However, actions and plans differ from country to country. The objective, which is common to all innovation systems of different countries, is to transform new discoveries in both new products for immediate commercial profit and in licensable intellectual property. A general perspective of each individual innovation system of the countries mentioned earlier will be exposed subsequently.

10.6.1 The USA

The National Nanotechnology Initiative (NNI) articulates corporate goals and specific objectives. It also describes collaborative activities between the various stakeholders and demonstrates a country focused on renewable energy, sustainable production and next-generation electronics (National Science and Technology Council 2014).

The NNI has a subcommittee that provides investment in all agencies to address the critical elements and to support the development and use of nanotechnologies. In addition, the program states that the subcommittee should interact with academia, industry, local government groups and international organizations. The subcommittee is also responsible for evaluating the progress and reviewing the strategic plan every three years.

In particular, the main objectives of the NNI strategic plan represent the concrete measures to be taken to collectively achieve the vision and NNI goals. The main areas of the program established in 2004 set a description of the main areas of the program components which were established in 2004. That is, to ensure the success of the initiative, to support research in interdisciplinary nanotechnology, to sustain and expand critical infrastructure, to train and inspire the next generation of scientists and engineers, and to support the responsible development and the nanotechnology transfer to commercial applications that benefit the American economy and society.

In detail, the first goal was to advance nanotechnology R&D programs. The second one aimed at promoting the transfer of new technologies into products for commercial and public benefit. The third objective was to develop and sustain educational resources, a skilled workforce and infrastructure and tools to advance the nanotechnology field. Finally, attention was also given to the development of sustainable-related innovation.

The NNI Strategic Plan promoted the transfer of technology, facilitating the engagement among agencies with key industries by providing public access to the results of nanotechnology research funded by the federal government, and helping to support the creation of a business environment conducive to the responsible development of nanotechnologies.

Funding is fundamental to the success of further nanotechnology development. The NNI has promoted educational programs that develop scientists, engineers, technicians, production assistants and laboratory personnel (including academic students and trainees) through multidisciplinary academic programs, industrial partnerships and R&D systems funded by the federal government. Infrastructural capacity, including the centers and research support facilities in nanomanufacture, nanoscale characterization, synthesis, simulation and modeling, has been developed through the NNI over the past 10 years.

The USA NNI strategic plan was well designed and allowed this nation to play an important role in the development of nanotechnological innovations worldwide. However, analysis of available sources do not reveal the US effort in the communication process with the public to gain public trust and thus promote the actual positioning of nanotechnology related products on the market. The analysis also indicates that the development of new policies for regulating and licensing intellectual property rights is necessary in order to promote knowledge transfer between universities and businesses.

10.6.2 Germany

In Germany, the measures adopted by the BMBF, from 1990 to 2006 in its nanotechnology innovation system, led to the development of a funding and support strategy for nanotechnology, considered essential for Germany to be competitive in the global market and solve future challenges in issues related to health, the environment and safety. Therefore, the BMBF has focused its funding in collaborative projects between partners from the scientific community and the business world. In order to achieve the above objectives, BMBF also funds some "accompanying measures" to support the industrial development of nanotechnology applications, and to fully exploit the potential of nanotechnology so as to benefit society.

The main goals of the system of innovation designed by BMBF were the following:

- achieve deeper scientific and technological knowledge in the field of nanotechnology;
- investigate the real potential of applications of specific nanotechnology-related products;
- organize clustering of resources and networking;
- inform people to enhance public understanding of nanotechnology;
- investigate societal implications and side effects/potential risks of nanotechnology;
- establish adequate education and training possibilities;
- arouse the fascination of young people for nanotechnology.

Germany is a good example of a proper implementation of the measures needed to create a good innovation system. The integrated approach followed by the German Ministry of Education and Research has resulted in achieving a high level of participation of companies in the research programs. The development was supported by an analysis of the market and of the patents granted and by the accompanying measures of the research programs and activities. The strengths of the German innovation system led to a very important aspect: sustainability. The sustainability of a product or a process is one of the keys for achieving public trust and credibility. This statement is even truer when the subject of interest is represented by a technology that is still in its emerging phase as is the case of nanotechnology.

Indeed, a well-designed strategic innovation plan underpins the leading position that Germany acquired in the field of nanotechnology over the last decade.

10.6.3 Russia

Meanwhile in Russia, nanotechnology-related systems of innovation emerged as a result of actions taken by public authorities. The institutional map consists of six layers, each with different functions. The top layer includes the general political bodies that develop a key role in determining the general political guidelines. The second layer involves institutions that formulate and implement science, technology and innovation policy. The third layer comprises the public sector, foundations and private investors that, along with federal and regional authorities, support the production and implementation of innovations financially (Gaponenko 2007).

One of the characteristics of the innovation system is that Russian companies were quite passive in fields related to nanotechnology (Gaponenko 2007). However, the creation of the private foundation by the ONEXIM[1] group led to some changes in expectations in the private sector as well as their beliefs and behaviors. The ONEXIM Group invests specifically in nano-energy. As such, certain trends can already be observed in the energy sector. Space and aircraft technologies will certainly be shaken by nanotechnology as Russia has a very strong position in those sectors where public and private investors have already expressed interest for nanotechnology. The fourth layer includes R&D oriented organizations, that are concentrated mainly in the public sector (about 90 %), in the Russian Academy of Sciences (RAS). The fifth layer includes organizations that facilitate the diffusion of technology, while the sixth layer encompasses companies in the Russian nanomarket. Gaponenko (2007) concludes that the nanotechnology sectoral system of innovation in Russia is unbalanced. For many years, special attention was paid to the development of infrastructure, but the nanoscience remains underdeveloped. The Russian nanoscience is funded by different sources involving the Ministry of

[1] ONEXIM group is one of the largest private equity funds in Russia. It has a diversified portfolio of investment in several industries comprising mining banking, real estate, media, energy and high tech.

Science and Education, the Ministry of Industry and Energy, the Ministry of Defense, the Ministry of Public Health, the Russian Academy of Sciences, the Russian Academy of Medical Sciences and the Russian Foundation for Basic Research. It was estimated that in 2006, the budget allocations in the field of nanoscience was about $350,000 (Gaponenko 2007).

At the beginning of 2006, two national nanotechnology development programs were launched to coordinate actions and resources and to face the challenges of the area. In 2007, President Putin announced that the Russian Federation Government would allocate about $7 billion in the development of nanotechnology. However, future trends and the impact of nanotechnology on the economy and competitiveness of Russian companies are going to be dependent not only on the allocated budget but also on how the money is spent within the sectoral system (Gaponenko 2007).

10.6.4 Iran

In Iran, the need to develop nanotechnologies and nanoscience was considered by the authorities a decade ago. The most important event since the beginning of research in nanotechnology was the formation of Nanotechnology Committee and Special Development (NDSC), which develops and launches 10-year development plans for the nanotechnology sector. Simultaneously, the government mobilized special financial resources for the NDSC to invest in the development of nanotechnology. The budget allocated to the NDSC has grown in recent years, but this funding is not sufficient to meet the industry's growing needs (Mohammadi et al. 2012).

Soon afterwards, the government strengthened the NDSC through: the creation of working groups on nanotechnology and infrastructure development in various ministries; the creation of the network of nanotechnology laboratories and the network of nanotechnology companies; the launch of the nanotechnology standardization committee; the creation of a network of incubators and technology parks; the creation of universities, research centers and centers of intellectual property services; and the allocation of financial resources to support theses and research in nanotechnology areas.

Following the strengthening of the NDSC, there has been an exponential growth of international publications of Iranian researchers in the field of nanotechnology, an increase in the number of theses and research related to nanotechnology and an increase in the number of international patents registered by Iranian residents. At the same time, this has led to changes involving an increasing number of active students and of specialized human resources in the field of nanoscience. The number of companies has also increased, which has led to a more specialized value chain. A reinforcement of nanoscience is expected to occur to stabilize and promote the institutionalization and legitimization (Mohammadi et al. 2012).

10.6.5 Sweden

Participants of the Swedish nanotechnology innovation system were identified in research groups from universities, nanotechnology related companies, funding bodies and governments.

In the year 2000 many nanotechnology related industries and companies were born in Sweden. In just 4 years there were 85 firms. Due to their novelty factor, many of them lacked customers.

During the same time period, research groups at universities also recorded remarkable growth, many of them changing their research line to topics related to nanotechnology and nanoscience.

A large number of financing bodies, both public and private agencies, are keenly interested in nanotechnology. They are characterized by having programs focusing on nanotechnology. What emerged from further analysis of the innovation system is mainly that there are no clear guidelines, defined rules or practical measures in order to promote effective collaboration and transfer of knowledge and technology between the various partners of the initiative.

Even with the existence of a systemic perspective and with high expectations regarding its performance in promoting the interaction among all actors, no effort was made to make fruitful collaborations. Moreover, despite the pressure on academia and industry, no concrete measure has been taken.

Although nanotechnology emerged as a potential growth area for the Swedish industry and even though the innovation system has had the opportunity to thrive, so far there are clear signs of it being at an early stage of development.

Unlike the German and American approaches to generate a successful innovation system, the Swedish strategy did not lead to the same results obtained in those countries. The main weakness is the lack of a national political interest that represents one of the main driving forces for creating innovations systems from emerging technologies. In addition, although scientific knowledge is strong, the technical knowledge is weak and a low collaboration among all stakeholders, including universities and industry, jeopardizes the diffusion of interdisciplinary knowledge.

10.6.6 South Korea

It was the desire to become an advanced nation in the world that led South Korea to an emerging position in nanotechnology. This new way of thinking was imperative to plan a national innovation system that would allow for the achievement of creative and decisive new technological discoveries. Such a system was used for the organization and management of innovative R&D projects and defining the role of all key actors involved (Song et al. 2007).

As a characteristic of the field of nanotechnology (still in its emerging phase) and the relatively new research model and market, the main task of designing a development strategy was represented by the uncertainties related to the technology and its market.

The Ministry of Science and Education (MOSE) was accused of planning, systematically, the technological development of South Korea, providing intensive support (for over more than five years) for strategic technologies with strong industrial applications. Therefore, the main objective of the MOSE program was to identify the specific areas in which South Korea would be prepared to achieve technological leadership, including high definition TV, medical technology, alternative energy sources and energy production processes. After that, a management system was introduced and a leader for each program was chosen and charged with overseeing all activities related to the R&D cycle (Song et al. 2007).

The ultimate goal set by the government aimed at achieving new technologies that enable to generate industries, jobs and new products. Unfortunately, the development of such a technology-driven approach to innovation has been slow and complicated as a result of the lack of technological expertise combined with a lack of field experts in the development process of many projects of emerging technologies.

Due to the relatively recent approach, oriented not to imitation but rather to creating new technological innovation, and to the lack of technological knowledge to perform the project plan, the South Korean system encountered some obstacles that slowed down the creation of innovations. The study of this nation is relevant because it shows that, in spite of all obstacles, it has a strong potential to succeed in creating nanotechnology innovations (Song et al. 2007).

10.7 Conclusion

One can conclude from Karaca and Öner's (2015) study that although the demand for nanoproducts may be latent, it is clear that systems of innovation will only emerge if the necessary conditions are met so that public and private sectors work in tandem.

Nowadays, it is possible to describe the general characteristics of nanotechnology systems. The current embryonic stage of nanotechnology SSI is marked by institutional shortcomings, the creation of new institutional infrastructures (companies and organizations), the emergence of networks, the existence of a learning system and the consolidation of the technological base. The knowledge base is of fundamental importance as a "training engine" in nanotechnology. Malerba (2002) pointed out that the SSI base differs among sectors, strongly affects innovative activities, the organization and the behavior of companies, as well as other agents within the sector (Malerba 2002; Gaponenko 2007).

Then, what are the specific features of the nanotechnology knowledge base?

First of all, nanotechnology encompasses a multidisciplinary and intersectoral challenge. It is characterized by a huge thematic range where the most important sub-disciplines are applied physics, material sciences, physical chemistry, condensed matter physics and molecular chemistry and biology. It is already possible to witness some trends and common actions on the formation of nanotechnology sectoral systems: the creation of interdisciplinary nanotechnology research centers and centers of excellence. Moreover, nanoresearch requires specific and expensive scientific equipment, which can only be provided with the involvement of the state and public bodies so that public and private research organizations can have up to date equipment and instruments required for demanding R&D in this area (Gaponenko 2007; Zweck et al. 2008; Zhao et al. 2003).

The multidisciplinary knowledge base leads to multidisciplinary and overlapping networks within the sectoral system, which might lead to a diverse and unfocused technology conglomerate as a result of the diverse paths of all the involved players. There is a clear interest in nanosciences involving researchers of many different sciences, creating new grounds for a multidisciplinary approach, combining scientific paradigms. Despite the large and ongoing investment, the development of nanotechnology is a recent theme and is in its experimental phase (Gaponenko 2007; Islam and Miyazaki 2009; Lo 2015).

It is not possible yet to determine exactly how the nanotechnology "platform" would be consolidated in the future. According to Heidenreich (2004), one might argue that it is still in its dirigiste perspective. Nanotechnology is in accordance with a science-based innovation pattern where scientific investments play an intertwined world between science and technology. The initial development of tools and instrumentation precedes and facilitates the scientific developments which, in turn, stimulate the technological development and commercial applications. Nanotechnology is thus marked by the emergence of certain non-core organizations, such as financial institutions, government agencies and technology transfer organizations. Moreover, risk funds and technological incubators also play a key role if the innovation system is to attain a networked perspective, according to Heidenreich (2004).

Nowadays, the market for nanotechnology is at an early stage but is expected to grow rapidly. Looking at recent trends we can highlight some peculiarities: spin-offs and micro and small enterprises will have a special role in this market—the creation of business relationships between companies and research centers and universities. Some regional differences may arise in the future: in the USA the role of small and micro enterprises is the most relevant, while in Europe research centers and universities are more prevalent (Gaponenko 2007; Kostoff 2012; Zweck et al. 2008).

Advances in emerging technologies play an indispensable role in the development of all sectors (Maine et al. 2014). Developed countries have succeeded in muddling through the intricacies of driving new technologies to the market developing appropriate opportunity-driven innovation policies. Funding nanotechnology projects increases each year. Moreover, mastering the knowledge and the experience gained involving nanotechnology projects is important to define the strategic direction of nanotechnology funding policies, as well as the results of ongoing research. For example new challenges are expected to flourish as the sustainability of nanotechnology, understood as the impact on the environment and on human health.

The experience of the Grenoble micro-nanotechnology cluster is very important from the innovation system point view (Potter 2009). As one can conclude, based on Potter's (2009) work, the following topics are very important for a sectoral system of innovation to work properly:

- The support by national administration for continuing and broadening R&D infrastructure and products so that social and economic benefits can be maintained in the nanotechnology long-term perspective.
- In order to respond to increased international competition, firms and R&D institutions from the nanotechnology industry must work in partnership. As nanotechnology involves massive public investments, in order to maintain a favorable investment firms and R&D institutions need to work together to achieve sufficient scale to be able to compete internationally.
- From the cluster perspective it is important to focus on the balance between diversity and specialization, as well as between exploitation and exploration. As such, the governance of the innovation system needs to take into account that too much investment on exploitation of current innovation / R&D activities might be important for the short-run, but will surely jeopardize the long-term perspective. On the other hand, too much focus on new / uncompetitive technologies may halt short-term research profitability. The diversity / specialization balance is also very important as nanotechnology might have pervasive effects across several industries, which might be jeopardized if the specialization is too narrow. These two important balances will certainly influence the international competitiveness of all players involved.
- Although most of the above mentioned studies refer to patenting and R&D activities quite exhaustively, the promotion of start-ups and new SMEs is very important as they involve the creation of a buffer of cooperative activities within the innovation system, as well as the dissemination of innovation across the system. If SMEs are able to perform adequately throughout the value chain, larger firms and R&D institution will be allowed to focus on their core activities, which enhances the cooperative dynamics throughout the whole innovation system.
- If start-ups and SMEs are to be competitive players, they need to overcome early financial barriers so that they achieve a proper scale to generate long-term revenues. As such, seed capital, business angles, among other private sources, need to be mobilized so that public funding can reach all players and technological complementarities among them are achieved.
- If financial support is imperative, entrepreneurship support activities are also important so that new start-ups have streamlined support underpinning exploration/diversity of the innovation system. Education, training, incubators and coordinating bodies need to be deployed so that entrepreneurship intentions are not hindered.

Based on Heidenreich's (2004) regional innovation dilemmas, the governance structure of dirigiste regions must be avoided because of the highly fragile institutional order threatened not only by companies' individualistic behavior, but also by the lack of technology widespread knowledge. A network perspective is needed, for example as shown by Moreira et al. (2007), so that governance structure maintains an entrepreneurial interest matching R&D infrastructure, the promotion of new ventures and innovative economic policy, so that nanotechnology may evolve towards a knowledge-base economy, in which all industry players achieve long-term, growth-based dynamic complementarities.

Despite being a radical innovation with economic and social pervasive effects, Smadja (2006) and Karaca and Öner (2015) found possible scenarios in which nanotechnology is doomed. As a consequence, one must seriously take into account the governance of the nanotechnology innovation system so that the go-nano perspective really takes place in the future. One thing is certain, more of the same perspective is not an option. As a result, an entrepreneurial outward looking perspective needs to be deployed so that new opportunities are embraced.

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Chapter 11
Impact of Venture Capital on the Growth of University Spin-Offs

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Abstract In recent decades, universities, as part of the triple helix, have assumed a role in contributing to economic development by transferring technology to society through, among other mechanisms, the creation of university spin-off firms (USOs). USOs usually face certain problems, namely a lack of funding and a low level of business management knowledge of their founders. Since USOs face these problems to a greater extent than other kinds of firms, venture capital might help them in gaining access to the lacking resources and exert a positive impact on their performance. This study addresses this issue, since knowing whether venture capital influences USOs' performance could help policy makers to plan their supportive policies better for these firms. The firms' performance is measured as sales growth. To answer our research question, we use a longitudinal dataset of 212 Spanish USOs over the period 2001–2010. The results show that venture capital partners have a positive effect on the USOs' growth. Consequently, we encourage the Government and academic authorities to design several policies for improving USOs' success.

11.1 Introduction

In recent decades, universities have been actively participating in the transfer of technology to society through the creation of companies known as university spin-offs (USOs) (Benneworth and Charles 2005). However, some papers have highlighted the low impact of USOs on the economy as the main critical aspect of

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using them to transfer technology from universities to society (Callan 2001; OECD 1998) due to their low level of growth (Chiesa and Piccaluga 2000; Mustar et al. 2007; Ortín and Vendrell 2010; Teixeira and Grande 2013).

The literature signals the lack of funding and the low management skills of the founders as two of the main problems of this type of company, presenting obstacles to business success. Companies with a university origin have more problems in obtaining financing in the long term than other companies (Shane 2004; Tobar 2004). There is also a lack of entrepreneurial and management capacity of academic entrepreneurs (Cantner and Goethner 2011; Ortín and Vendrell 2010), as well as experience in the sector (Wennberg et al. 2011; Zahra et al. 2007).

Therefore, the creation and consolidation in the productive sector of USOs present a series of specific problems, whose solution requires the involvement of actors for which an approach is necessary that involves actors from the university, public, and private sectors. This heterogeneity of participants in the process of the creation of USOs is highlighted by different authors, such as Etzkowitz (2003) in his model of the triple helix, in which the university, the business or private sector, and the public sector interact, as well as more recent works (Farinha and Ferreira 2012) under the name of "triangulation of the triple helix". The creation of a USO is a process driven by the expectation of benefitting entrepreneurs, researchers, and/or the whole of society. Thus, while all the agents of the triple helix are interested in completing the process, the incentives that drive each one do not always coincide, producing conflicts resulting from the different perspectives of each group. In this sense, the creation of a USO depends on the existence of interactions between the different agents and commitments being achieved to distribute costs (certain) and benefits (uncertain), in a manner that is acceptable to all involved.

The support and participation of universities and public administration in the creation of USOs have increased significantly in recent years, but the same does not seem to apply to industrial partners and investors. These private investors are a key factor for these projects to succeed. Several papers find that the reason why most USOs do not achieve high growth is usually the lack of availability of external funding to exploit business opportunities, making access to capital one of the most relevant aspects of university entrepreneurship (Evans and Leighton 1989; Veciana 2005). This gap between the demand for financial resources of entrepreneurs and the availability of capital from investors has been detected in countries such as the United States (Shane 2004), the United Kingdom (Bank of England 2003), and Europe in general (European Commission 2000), causing a direct effect on the companies' ability to develop (Brown and Uljin 2004). The entry of private investors and industrial partners is a source of funding in the initial phases and also brings business experience and abilities, complementing the original entrepreneurial team that usually consists of researchers, who are highly specialized in their area of knowledge but have little or no training in the commercial aspects and management capacities (Ortín et al. 2007).

In this sense, the role of venture capital in value creation has been studied relatively frequently in the literature. Most of the works point out that venture capital investors play an important role in the financing and commercial development of new technologies (Kortum and Lerner 1998). Venture capital investors bring to the companies not just financial participation but also support in the management of a portfolio of contacts (Amit et al. 1998; Gompers and Lerner 1999). These investors make an important contribution by closing the financing deficit for young innovative companies and facilitating professional management for them. In this sense, USOs are a group of firms in which the use of this alternative method of financing could generate major value and utility; as we pointed out, two of the main problems of this type of company are the lack of financing and managerial training of the founders.

The objective of this work is to determine whether the presence of venture capital contributes to the success of USOs. In the literature, a large number of works studying the relationship between the receipt of venture capital and firm performance (for a detailed description see Schefczyk 2000) generally find a positive relationship (Jain and Kini 1995; Lerner 1999; Sapienza 1992). Therefore, there is evidence that the presence of venture capital is an important factor in explaining the differences in the performance of firms (Hellmann and Puri 2000), although there are no works that consider this effect for companies created in universities. For this reason, we aim to determine whether obtaining venture capital influences the business growth of USOs.

To achieve our goal, we have structured this work as follows. After this introduction, in the second section, we present the theoretical framework that allows us to establish the hypothesis to investigate in this study. In the third section, the sample and the econometric models used are presented. Next, we provide the results of the empirical and descriptive analyses and conclude with the main findings and recommendations.

11.2 Theoretical Framework

Firm growth has been analysed with relative frequency in the economic literature (for a detailed review see Coad 2009). Due to the recent development of spin-offs as a way to transfer technology from universities to society, over the last decade, a few studies began devoting attention to the growth of this type of company. Most of them are focused on countries where the emergence of this type of firms has reached a certain level of maturity, such as the United States, Sweden, Germany, the United Kingdom, Italy, or Belgium. However, not many studies consider universities of the south of Europe, due to the more recent character of this type of activity (Yagüe and March 2011).

Despite the fact that in the case of USOs venture capital funding is considered to be of great importance, only the work by Zhang (2009) studies its effect on firm growth. Using a sample of 704 USOs and 5,655 independent American companies over the period 1992–2001, the author finds a positive effect of the amount of funds raised in the first round of venture capital financing on the number of employees, as well as a negative effect of the age at which the first round was performed. In this sense, it is expected that having a larger number of employees will make the first round of venture capital more successful and increase the capital raised.

For the Spanish case, Yagüe and March (2011), in their study of biotechnological USOs, consider the presence of venture capital partners but do not test the existence of a relationship between this and the USOs' growth.

Therefore, to the best of our knowledge, only the study by Zhang (2009) analyses the effect that the venture capital partners may have on the USOs' growth. However, the literature on technology-based firms, which usually constitute a significant group within academic spin-offs, points out the access to venture capital as one of the determinants of growth for this type of firm (Colombo and Grilli 2010).

Thus, from a theoretical point of view, there are several reasons that would explain why venture-backed USOs can obtain better results than non venture-backed USOs. Firstly, the role played by venture capital partners tends to be highly active, both in strategic decision making and in the day-to-day operation of the company (Bertoni et al. 2011; Colombo and Grilli 2010). Such monitoring is especially important in the case of USOs, since the literature often attributes to academic entrepreneurs a negative effect on their companies' growth due to the lack of management skills and direct relation to business activities (Cantner and Goethner 2011; Ortín and Vendrell 2010; Ortín et al. 2007, 2008), as well as the lack of experience in the sector (Wennberg et al. 2011; Zahra et al. 2007). This negative effect may be partly offset by the experience of a venture capital partner and its role as a "coach" in the management of the company (the coach effect).

Secondly, the presence of venture capital helps to overcome the due diligence process in which the business potential is carefully scrutinize (Wright et al. 2006). Passing this process acts as a positive "signal" (the signalling effect) to third parties (Bertoni et al. 2011). This signalling effect improves the image of the company, facilitating its access to external resources to greater extent than non venture-backed companies. Since academic spin-offs traditionally emerge in non-commercial environments (Wright et al. 2006), they are subject to a greater extent to asymmetries of information that can be mitigated by the presence of venture capital partners emphasizing this signalling effect.

Thirdly, USOs commercialize technologies and knowledge developed by academic research whose commercial value is difficult to assess. Since venture capitalists are trained in identifying the hidden value of new business (Bertoni et al. 2011; Colombo and Grilli 2010), especially in high-technology sectors, sometimes they are the only investors who "dare" to participate in this type of company by providing financing and mitigating the tight financial constraints (Colombo and Grilli 2010; Wright et al. 2006). This positive effect is attributed to the role of "scout" or explorer played by venture capital companies in emerging sectors (the scout effect).

Opposite to the previous arguments (the coach, signal, and scout effects), the literature also points out that the agency conflicts between the venture capitalists and the entrepreneurs may negatively affect the firm performance. These agency conflicts arise when the venture capitalists chase targets and strategies that differ from those of the founders, as well as their incorporation into the ownership involves certain risks of appropriation of the business that they could exploit themselves without the entrepreneurs (Bertoni et al. 2011).

Despite these arguments against venture capital, we consider that the arguments for a positive relationship between venture capital and the USOs' growth are stronger. Thus, in the particular case of the Spanish USOs, venture capital might mitigate the main problems faced by this kind of firm, namely a lower level of managerial ability/experience of its founders and the lack of financing (Ortín et al. 2007; Rodeiro Pazos et al. 2014).

As a result, the fundamental assumption of our work was raised in the following terms: "the presence of venture capital partners has a positive effect on the growth of USOs".

11.3 Methodology

11.3.1 Sample

In the literature, there is no single definition of the concept of a USO (Pirnay et al. 2003). In this work, given that the primary data come from Red OTRI (Network of Technology Transfer Offices of the Spanish universities), we follow its definition considering a USO as a firm based on knowledge generated at a university, but not necessarily founded by university staff (Red OTRI de Universidades 2011).

The study sample was obtained by merging two databases: Red OTRI (2012), which is made up of 700 USOs, and Rodeiro-Pazos et al. (2008), which consists of 317 USOs. After dropping duplicates, we obtained a name list of 589 USOs. Only 569 of them were found in SABI database, which contains annual financial statements of the Spanish firms. Since the study analyse companies established between 1 January 1998 and 31 December 2010, those USOs formed prior to 1 January 1998 were discarded, resulting in a sample of 547 USOs. Finally, we also discarded the USOs without information concerning their shareholders, which is essential to study the effects of the venture capital partners on firm growth. This third and final screening resulted in a final sample formed by 212 USOs.

Having obtained the study sample, we built a dataset using as sources of information the SABI database, for complete information concerning the financial and business characteristics of the USOs in the sample, as well as the Espacenet database, for information about the firms' patent activity. As result, we constructed a unique and original longitudinal dataset (2001–2010). Figure 11.1 summarizes the steps followed in this process.

11.3.2 Model Specification

Panel data methodology was used to estimate the models. Two issues were considered in making this choice. Firstly, unlike cross-sectional analysis, panel data allowed us to control the unobservable heterogeneity. This aspect is crucial in our research, since the decision to use venture capital is very closely related to the firm' characteristics. Secondly, using the panel data methodology we could deal with the endogeneity problem. The endogeneity problem was likely to arise since the dependent variable (firm growth) might also explain some independent variables in our model (leverage or return on assets, for example). The basic specification of our model is as follows:

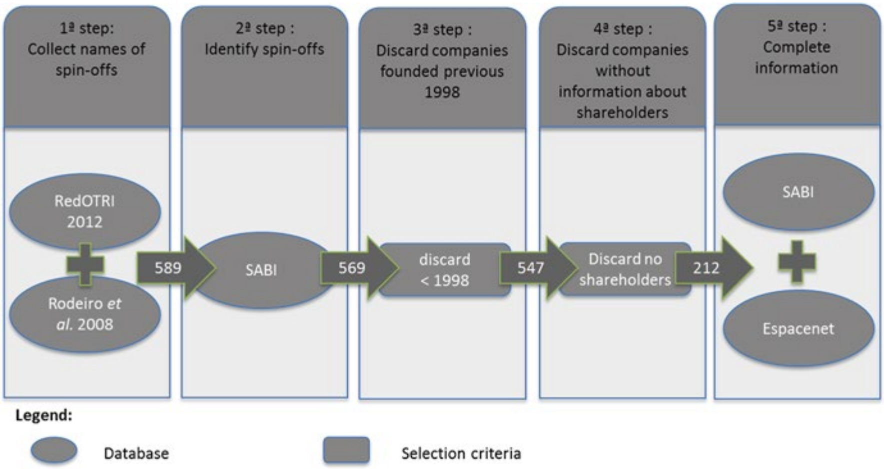


Fig. 11.1 Construction of dataset

$$Growth_{it} = \beta_1 venturecapital_i + (\beta_2 lnage_{it} + \beta_3 lnagesquare_{it} + \beta_4 loc\_four_i + \beta_5 sec\_at_{it} + \beta_6 lntotalassets_{it} + \beta_7 lntotalassets\ square_{it} + \beta_8 diversification_i + \beta_9 limitedcompany_i) + (\beta_{10} roa_{it} + \beta_{11} ca\_cd_{it} + \beta_{12} leverage_{it} + \beta_{13} lecveragesquare_{it} + \beta_{14} rot\_ta_{it}) + (\beta_{15} industrialpartner_i + \beta_{16} npat\_a_{it} + \beta_{17} npat\_b_{it}) + \alpha_i + \lambda_t + \varepsilon_{it}$$

where the error term has several components; in addition to the individual effect or specific effect of each company (α_i), λ_t measures the time-specific effect by the time dummy variables, so that the effect of macroeconomic variables is controlled, and ε_{it} is the random disturbance.

Growth is commonly regarded as the most important indicator of performance in new companies (Wennberg et al. 2011). Particularly, sales growth shows the acceptance of the firm' goods and services in the market, which turns it into a good indicator of the firm' success. However, this variable also presents certain limitations, as it could show the possibility that a company grows with a low level of sales. This could be the case of a significant number of USOs that are technology intensive and need a long pre-commercial stage to develop technologies before moving into the market maturity stage. In spite of these limitations, our dependent variable was sales growth, which is measured as the natural logarithm of the difference in the sales of the business (Wennberg et al. 2011).:

$$\text{Growth}_{i,t} = \ln\left(\frac{\text{Sales}_{\ i,t}}{\text{Sales}_{\ i,t-1}}\right)$$

The main independent variable (VENTURECAPITAL) was a time-invariant dummy variable; that takes the value one if the USO had venture capital financing and zero otherwise, as in the works of Bonardo et al. (2009) and Yagüe and March (2011).

In addition, we incorporated a series of control variables grouped into three vectors of explanatory variables: firm-specific characteristics, firm financial performance, and integration and innovation characteristics.

With regard to firm-specific characteristics, firm size was measured as the natural logarithm of the total assets (LNTOTALASSETS). In addition, age was included as the natural logarithm of the number of years since the constitution of the company (LNAGE). To test the existence of non-linear relationships between both variables and firm growth, these variables squared (LNTOTALASSETSSQUARE and LNAGESQUARE) were incorporated. We included a dummy variable for the firms in high-tech industries (SEC_AT), according to the Eurostat classification. Eurostat uses the aggregation of the manufacturing industry according to technological intensity and based on NACE Rev.2 at 2-digit level. A dummy variable was also created for the firms located in Catalonia, Madrid, Valencia, and Andalusia (LOC_FOUR). These four regions account for the largest number of USOs and the majority of research infrastructures related to technology transfer. A dummy variable for private limited liability companies (LIMITEDCOMPANY), as compared to public limited liability firms was also considered. Additionally, as a proxy of firms' diversification we used a dummy variable coded one if the firm had exported, and zero otherwise (DIVERSIFICATION).

Regarding firm financial performance, four financial ratios were used: the return on assets (ROA) (earnings before interests and taxes/total assets), the current ratio (CA_CD) (current assets/current debt), the total assets turnover (ROT_TA) (sales/total assets), and the leverage ratio (LEVERAGE) (debt/total assets). To test the existence of non-linear relationships, the last variable was also squared in the models (LEVERAGESQUARE).

Finally, as proxies for the firm' characteristics of integration and innovation, three variables were considered. Since the information handled did not show the founders' experience in the industry, a dummy that takes the value one if the firm had industrial shareholders (INDUSTRIALPARTNER), and zero otherwise, was used as a proxy. In addition, two variables that gather information about patents were used: the number of the firm's patent applications annually filed at the Spanish Patent and Trademark Office, the European Patent Office (EPO), the US Patent and Trademark Office (USPTO) or submitted to a Patent Cooperation Treaty (NPAT_A), and the number of the firm's patent annually granted by the Spanish Patent and Trademark Office, the EPO and the USPTO (NPAT_B).

Table 11.1 shows the above variables as well as how they were measured and the expected sales growth relationship.

11.4 Empirical Results

11.4.1 Descriptive Analysis

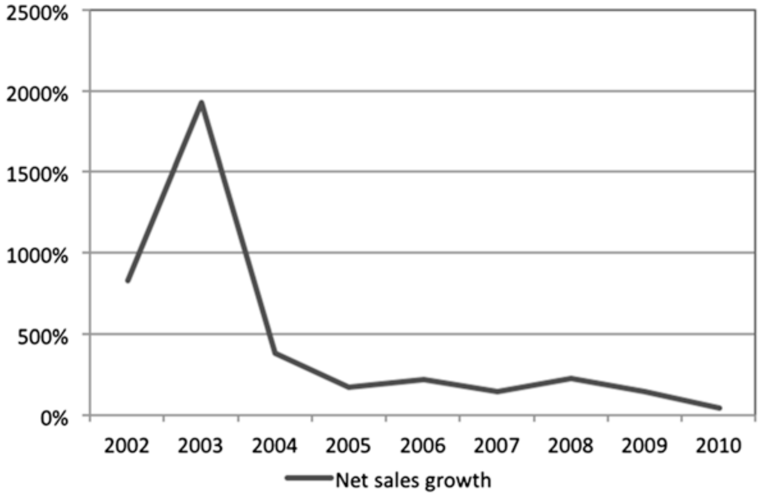
Graph 11.1 shows the rates of sales growth in the Spanish USOs over the period 2002–2010.

The annual average sales growth rate is 303 %, showing that the firms experienced significant growth rates over the period analysed, which were always superior to 100 % except in the last year.

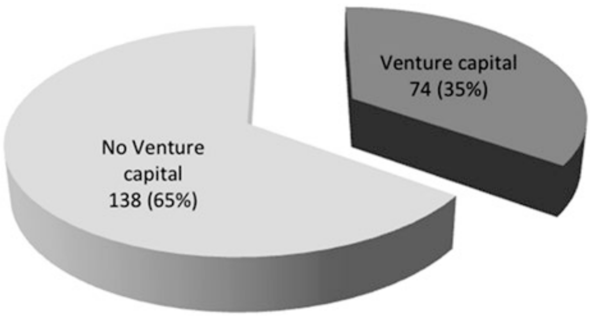
Of the total number of USOs that constitute our sample, 74 firms, representing 35 %, had venture capital partners (Graph 11.2).

Table 11.1 Definitions of independent variables and predictions

Variable		Definition	Sales Growth
Venture capital	VENTURECAPITAL	One if the firm had venture capital financing, and zero otherwise	+
Age	LNAGE	Natural logarithm of the number of years since the establishment of the firm	+
	LNAGESQUARE	Natural logarithm of the number of years since the establishment of the firm squared	-
Location	LOC_FOUR	One if the firm is located in Catalonia, Madrid, Valencia, or Andalusia, and zero otherwise	+
Sector	SEC_AT	One if the firm is in high-tech industries, and zero otherwise	
Size	LNTOTALASSETS	Natural logarithm of the total assets	+
	LNTOTALASSETSSQUARE	Natural logarithm of the total assets squared	-
Diversification	DIVERSIFICATION	One if the firm had exported, and zero otherwise	+
Legal form	LIMITEDCOMPANY	One if the firm is a limited company, and zero otherwise	-
Profitability	ROA	Earnings before interest and taxes/total assets	+
Liquidity	CA_CD	Current assets/current debts	+
Leverage or financial structure	LEVERAGE	Debt/total assets	+
	LEVERAGESQUARE	Debt/total assets squared	-
Activity or efficiency	ROT_TA	Sales/total assets	+
Experience in the industry	INDUSTRIALPARTNER	One if the firm had industrial, and zero otherwise	+
Innovation	NPAT_A	Number of the firm's patent applications annually filed	-
	NPAT_B	Number of the firm's patent annually granted	+



Graph 11.1 Rates of sales growth in the Spanish USOs (2002–2010)



Graph 11.2 Presence of venture capital in the Spanish USOs' equity

Table 11.2 shows the descriptive statistics for the dependent and independent variables. This information is displayed both for the overall sample and for the two sub-samples (venture-backed USOs and non venture-backed USOs), including a test of the mean differences between these two groups of companies.

This sample of USOs consists mainly of SMEs with the legal form of a limited liability company and an average age of 4.75 years; approximately 70 % of them are located in Catalonia, Madrid, Valencia, and Andalusia. Less than half of these companies operate in high-tech sectors (47.1 %) and only 15 % had exported. The average return on assets is negative, at around -7 %, while the average liquidity appears

Table 11.2 Differences in USOs with and without venture capital partners: *t*-test

	TOTAL SAMPLE		NON VENTURE-BACKED USOs		VENTURE-BACKED USOs		*t*-test	
Variable	Obs.	Average	Obs.	Average	Obs.	Average	t	P > 0
growth[a]	907	3.036	619	1.838	288	5.610	-1.978**	0.048
age[a]	1436	4.752	941	4.929	495	4.416	3.345***	0.001
loc_four	1436	0.718	941	0.726	495	0.703	0.912	0.362
sec_at	1436	0.471	941	0.426	495	0.558	-4.776***	0.000
totalassets[a]	1285	1,674.246	835	894.758	450	3,120.629	-4.836***	0.000
diversification	1436	0.152	941	0.126	495	0.200	-3.706***	0.000
limitedcompany	1426	0.886	931	0.932	495	0.798	7.743***	0.000
roa	1271	-0.069	827	-0.043	444	-0.117	3.135***	0.002
ca_cd	1263	3.388	824	2.923	439	4.262	-2.843***	0.005
leverage	1285	69.166	835	73.382	450	61.342	4.898***	0.000
rot_ta	1202	0.881	803	1.101	399	0.440	10.643***	0.000
industrialpartner	1410	0.351	915	0.329	495	0.392	-2.367**	0.018
npat_a	1416	0.285	941	0.177	475	0.497	-4.908***	0.000
npat_b	1416	0.067	941	0.053	475	0.095	-2.119**	0.034

Note: *p < 0.1; **p < 0.05; ***p < 0.01

[a]Variables are not in logs

to present no problems since the average current ratio is over 3. As regards the presence of industrial partners, only 35 % of the companies have an investor of this type. The average number of patent applications filed during the period of analysis is 0.285, while the average number of patents granted is 0.067.

Focusing on the differences between the venture-backed USOs and the non venture-backed USOs, the former has significantly higher sales growth rates. Likewise, they have a larger size, are more geared toward the international market, offer goods or services of high technology to a greater extent, and show greater liquidity. In addition, the average values for the presence of industrial partners and the number of patents are significantly higher in venture-backed USOs. However, the non venture-backed USOs show significantly higher values with regard to the return on assets, leverage, and efficiency in the use of their assets. In addition, they are mostly limited companies in this group.

11.4.2 Multivariate Analysis

The results of the estimation are shown in Table 11.3.

The results show a positive relationship between the presence of venture capital partners and sales growth. Therefore, the hypothesis on the positive effect of venture capital partners on the USOs' growth is validated. The funding provided by the venture capital investors to these companies, in which, due to the uncertainty inherent in their high technological activity, more traditional funders do not want to invest (the scout effect), may boost their above-average growth. In addition, the active role played by venture capital investors in the management of the firm could partly offset the lack of entrepreneurial and management skills of the academic founders (the coach effect). Furthermore, the venture-backed USOs could gain access to resources that would be out of reach without the benefits of the image derived from their alliance with the venture capital partner (the signalling effect).

In addition, sales growth is determined positively by the return on assets and the efficiency in the use of assets and negatively by the level of sales of the previous year. In addition, there seems to be an optimum size after which the sales decrease. There is also evidence of the existence of the "liability of adolescence", suggesting that in the first years of its operation a company would suffer in a reduction in sales but that exceeding a certain market adjustment would allow growth.

11.5 Conclusions and Recommendations

The objective of this study was to verify whether venture capital influences the firm growth of USOs. To answer this question, we empirically analysed the impact of the presence of venture capital investors in the growth of 212 Spanish USOs over the period 2001–2010, of which 74 were venture-backed firms.

Table 11.3 Estimation of the sales growth: generalized method of moments

Variables	Coef.	Standard error
venturecapital	0.037**	(0.012)
grouth$_{t-1}$	−0.218***	(0.040)
yr2004a	0.128	(0.212)
yr2005a	−0.179	(0.144)
yr2006a	−0.076	(0.105)
yr2007a	−0.202	(0.104)
yr2008a	−0.107	(0.105)
lnage	−3.121**	(0.961)
lnagesquare	0.719**	(0.256)
loc_four	0.013	(0.011)
sec_at	0.007	(0.009)
lntotalassets	1.231***	(0.279)
lntotalassetssquare	−0.074***	(0.018)
diversification	−0.011	(0.012)
limited company	−0.007	(0.014)
roa	1.197***	(0.214)
ca_cd	0.000	(0.014)
leverage	0.004	(0.004)
leveragesquare	0.000*	(0.000)
rot_ta	0.223**	(0.067)
industrialpartner	−0.007	(0.010)
npat_a	0.020	(0.022)
npat_b	−0.131	(0.111)
_cons	−1.637	(1.186)
No. of observations	654	
No. of firms	162	
Instruments	203	
Freedom grades	23	
Test F	7.84	
F p-val.	0.000	
Test AR(1)	−2.89	
AR(1) p-val.	0.004	
Test AR(2)	−1.61	
AR(2) p-val.	0.107	
J Hansen statistic	131.22	
J Hansen p-val.	0.997	

Note: * $p<0.05$; ** $p<0.01$; *** $p<0.001$
Corrected standard errors (Windmeijer 2005) are presented in parentheses

The empirical results show that the presence of venture capital partners has a positive effect on the sales growth in Spanish USOs.

Based on this result, a series of policies is proposed that could be applied from the sphere of universities and/or public administrations to promote the participation of venture capital investors in USOs to make them economically and socially viable projects. In this sense, one of the main problems of potential investors is the low level of awareness of and confidence in companies created in universities and the underlying technologies on which they are based. Policies are required to allow companies born in universities to reduce the information asymmetries and facilitate the participation of potential investors in the spin-offs by partly decreasing their risk. Some of these policies could be:

a. To create a database of USOs, so that potential investors will be conscious of the possibilities of investing in technologies that have been developed in academic institutions.
b. To strengthen the role of universities in finding financing. Universities and TTOs should act as a broker between spin-offs and potential investors.
c. To organize investment rounds in which academic entrepreneurs can introduce the technology base of the company to private investors.
d. To facilitate investor access to a panel of external experts who can advise them on the core technology of the USOs' products and services.
e. To enable access to an external report on the commercial viability of the USOs, since this tends to be one of the key aspects of a business.
f. To facilitate co-financing of the companies by the public administration. In this way, the three agents that form the triple helix could collaborate. In addition, a greater guarantee on their investment will be offered to venture capital investors.
g. To create a society of mutual guarantees specific to USOs. Thus, guarantees will be raised in enterprises born in universities and the risk of non-payment will decrease and will encourage the participation of private investors.
h. To offer tax advantages to venture capitalists and especially to business angels to make it more attractive to invest in companies created in universities.

One of the main contributions of this work is the consideration of venture capital as a determinant of the growth of USOs, because no such previous study has considered this variable and this is the first to do so for the Spanish case. In addition, it built a unique dataset that considers a broad time period and takes into account other variables (size, age, leverage, and profitability, among others) that the traditional literature has identified as determinants of firm growth. Finally, by using the panel data methodology and applying the GMM estimator, this work controlled the possible endogeneity problems that may have arisen in the estimates.

However, this work also has limitations. In this regard, the availability of information was the main problem encountered. The SABI database, the main source of information used in this work, provides updated information on the composition of the shareholders of the companies; however, it does not provide historical information about the same. Therefore, we were not able to see the date on which the venture capital partners become shareholders, data that would enable us to undertake a study in greater depth.

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