PALGRAVE STUDIES IN DEMOCRACY, INNOVATION, AND ENTREPRENEURSHIP FOR GROWTH

THE QUADRUPLE INNOVATION HELIX NEXUS

A Smart Growth Model, Quantitative Empirical Validation and Operationalization for OECD Countries

Edited by

Sara Paulina De Oliveira Monteiro and Elias G. Carayannis

Palgrave Studies in Democracy, Innovation, and Entrepreneurship for Growth

Series Editor

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Sara Paulina De Oliveira Monteiro • Elias G. Carayannis
Editors

The Quadruple Innovation Helix Nexus

A Smart Growth Model, Quantitative Empirical Validation and Operationalization for OECD Countries

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For Bernardo Lucas Monteiro Maio
For Manuel Salvador Monteiro Maio

In memory of my inspiring grandparents Maria Augusta Marques, Manuel Domingues de Oliveira, Maria da Conceição da Cruz, Manuel Augusto R. Monteiro

In memory of Helena do Rosário de F. da Cruz Monteiro

Foreword

Economic growth has been sluggish since the onset of the international financial crisis. This is particularly noticeable in the most advanced countries, but also more recently in the emerging market economies, which have been affected by the end of the commodity supercycle and the slowdown of the Chinese economy.

Even though the hangover from the financial crisis has played a role for such a low-growth environment, the main culprit for the slowdown in world growth has been the significant decline in productivity growth throughout the globe. Virtually no country has been left unscathed by this productivity slowdown, from Organization for Economic Cooperation and Development (OECD) countries to developing countries. What explains then the productivity slowdown?

Several factors have certainly contributed, from lower investment in knowledge-based capital, to lower business dynamism in some countries, as well as the lack of (or insufficient) product market and pro-competition reforms. However, recent research at the OECD has also shown that another prominent contributing factor for the productivity slowdown has been the slower rate of diffusion of technologies around the world,[1] with a particular incidence in the services sector. According to this research, productivity growth at the top frontier firms has remained strong since the 1990s, even though it slowed down somewhat after the international crisis. In contrast, productivity growth of non-frontier and laggard firms has been weak or virtually inexistent, even before the crisis.

This obviously begs the question whether such sharp difference in performance is merely transitory or is due to structural factors. Namely, is there a problem with the so-called diffusion machine? If so, what is impeding a faster diffusion of the productivity gains from the frontier firms to the non-frontier or laggard firms? Why is the service sector more affected by the diffusion problem than the industrial sector? What polices can be advanced to fix the problem? I have no doubt that in the next few years these will be bit topics of debate as well as fruitful research avenues. I am also certain that solving this productivity puzzle will be instrumental to improve the productivity (and hence the growth) performance of countries.

What can countries do? What policies should be used to boost productivity? At the top of the agenda, continuing to improve and expand the global innovation frontier will be key. Without innovation and without new ideas, the productivity slowdown will surely become structural, which will have a tremendous negative impact on economic growth and on job creation.

For all these reasons, research on innovation and diffusion is fundamental to address all these policy challenges. The private sector will continue to have a crucial role in the innovation process. More public investment in basic research will be essential to foster more innovations. And universities and research centres will remain instrumental in knowledge creation and diffusion.

In this context, this book *Quadruple Innovation Helix Nexus* presents new research and empirical evidence on the linkages between all these sectors (public, private, industry and the universities) in the innovation and diffusion processes. This so-called Quadruple Innovation Helix is absolutely indispensable to boost innovation and productivity growth. The book also presents and discusses the role of policymaking in the innovation process, as well as the policy challenges that policymakers face in dealing with these matters.

All in all, this book not only adds to the literature on the Quadruple Innovation Helix nexus but also presents new evidence on the links between innovation and productivity growth. The book also examines the innovation and entrepreneurship ecosystems of OECD countries, as well as the existing policies and best practices. For all these reasons, this book is essential reading for those interested about these issues that will largely shape our future.

Director   Alvaro Santos Pereira
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Note

1. *The Future of Productivity*, 2015, Paris: OECD.

Acknowledgments

Three years ago, I was defending my PhD thesis in economics at GREDEG-CNRS, Université Nice Sophia Antipolis, Nice, France, about the impact generated by the technological infrastructure on innovation and economic growth in OECD (Organisation for Economic Co-operation and Development) countries. I drew inspiration from the Quadruple Helix Innovation (QHI) Systems Conceptual Framework in order to build a theoretical model of economic growth to assess the role played by a set of technological infrastructures, such as technology parks, incubators, and centers of technology transfer, as well as other institutions belonging to different "innovation ecosystems", in the presence of innovation open systems and the "mode 3" of knowledge production. My QHI theory choice on National Innovation Systems (NIS) was based on my participation in CLIQ, an INTERREG IVC project, hosted by the City of Jyväskylä, Finland, during 2008–2011, when I had my first contact with Elias G. Carayannis, the creator of the QHI and with the publications with David F.J. Campbell as co-author in the related 2005 Praeger book[1] on knowledge creation, diffusion and use, where they discussed this concept first as well as in the 2009 *IJTM* (*International Journal of Technology Management*) paper[2] on the QHI and mode 3 of

[1] http://www.worldcat.org/title/knowledge-creation-diffusion-and-use-in-innovation-networks-and-knowledge-clusters-a-comparative-systems-approach-across-the-united-states-europe-and-asia/oclc/474773149.

[2] http://www.inderscienceonline.com/doi/abs/10.1504/IJTM.2009.023374.

knowledge production systems (also discussed in the 2005 book). Upon my first contact with the QHI theory, I realized how impressive, and full of potentialities, this theory was. Indeed, it describes a new economic reality where innovation is seen as the result of co-creation between businesses, citizens, universities, and the government, in a framework characterized by the existence of partnerships, networks of collaboration and symbiotic relationships. The PhD jury extolled the innovative way to tie QHI theory to growth models. Some days later, after returning to Portugal, Carayannis offered me the chance to co-edit this book. So, first, I would like to thank my co-editor for entrusting me with the enormous challenge, and also for the assistance, advice, and critical involvement during all this process.

THE QUADRUPLE INNOVATION HELIX NEXUS: A SMART GROWTH MODEL, QUANTITATIVE EMPIRICAL VALIDATION AND OPERATIONALIZATION FOR OECD COUNTRIES has different authorships. The book reunites writings by several contributors, from many walks of life, countries and continents, yet all sharing the same recognition that the QHI theory is critical to understanding innovation processes and economic growth and for the design of public innovative policies. The editors would like to thank the authors: David F.J. Campbell, Evangelos Grigoroudis, Óscar Afonso, Maria João Cabral Almeida Ribeiro Thompson, Maria Adelaide Pedrosa da Silva Duarte, Manuel Laranja, Carlos Rodrigues, Filipe Teles, Valerie Brett, Bill O' Gorman, Isabel Caetano, Catarina Selada, António Bob Santos, and Sandro Mendonça.

The authors of Chap. 9 would like to thank the members of the Portuguese clusters for their collaboration in this study. The research for Chap. 6 was conducted as part of the KTForce project, supported by the INTERREG IVC Capitalization Program and co-financed by the European Regional Development Fund (ERDF).

I am also grateful to Maria João Cabral Almeida Ribeiro Thompson, Óscar Afonso, and Maria Adelaide Pedrosa da Silva Duarte, my mentors and experts, without whose confidence, support, patient, professionalism, and dedication, this book would have been impossible.

To Claude Berthomieu and João Sousa Andrade for always being there, teaching, helping and encouraging, and reading and criticizing—two inspiring economists that I have the chance to have as teachers and as friends. I have been deeply influenced by their passion for macroeconomics.

The editors would like to thank the several endorsements received for the book, as well as ALVARO SANTOS PEREIRA, director of the Country

Studies Branch at OECD and the previous Portuguese economy minister, for honoring them by writing the foreword of this edition.

I want, last but not least, to acknowledge the "four pillars" of my family, for their unfailing love and support through this scholarly endeavor: my mother, Mª Helena Marques de Oliveira Monteiro, and my father, Litério da Cruz Monteiro; my husband, Hugo Filipe Maio Neto; my two brothers, Jorge Ricardo de Oliveira Monteiro (and family) and Tiago André de Oliveira Monteiro; and my two little boys, who were born during this period, Bernardo Lucas Monteiro and Manuel Salvador Monteiro.

Mira- Coimbra, Portugal Sara Paulina De Oliveira Monteiro
December, 2016

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CHAPTER 1

Introduction

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1.1 The Quadruple Helix Innovation Systems Conceptual Framework

The Quadruple and Quintuple Helix Innovation Systems Conceptual Framework focuses on the cross-linkages, cross-references, and co-evolution of knowledge economy, knowledge society, and knowledge democracy in context of environment and social ecology. The Quadruple and Quintuple Helix Innovation Systems Conceptual Framework develops a progressive vision of development in society, democracy, and economy, emphasizes the qualities of sustainable development, and understands knowledge (knowledge production, knowledge creation) to be essential for innovation (knowledge application, knowledge use) in innovation systems. In more particular, the

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Quadruple and Quintuple Helix Innovation Systems Conceptual Framework has interwoven the ideas of Mode 1, Mode 2, Mode 3, and Triple, Quadruple, and Quintuple Helix.

University research, in a traditional understanding and in reference to universities in the sciences, focuses on basic research, often framed within a matrix of academic disciplines, and without a particular interest in the practical use of knowledge and innovation. This model of university-based knowledge production is also being called "Mode 1" of knowledge production (Gibbons et al. 1994). Mode 1 is also compatible with the linear model of innovation, which is often being referred to Vannevar Bush (1945). The linear model of innovation asserts that first there is basic research in university context: gradually, this university research will diffuse out into society and the economy. It is then the economy and the firms that pick up the lines of university research, and develop these further into knowledge application and innovation, for the purpose of creating economic and commercial success in the markets outside of the higher education system. Within the frame of linear innovation, there is a sequential "first-then" relationship between basic research (knowledge production) and innovation (knowledge application).

The Mode-1-based understanding of knowledge production has been challenged by the new concept of "Mode 2" of knowledge production, which was developed and proposed by Michael Gibbons et al. (1994, pp. 3–8, 167). Mode 2 emphasizes a knowledge application and a knowledge-based problem-solving that involves and encourages the following principles: "knowledge produced in the context of application"; "transdisciplinarity"; "heterogeneity and organizational diversity"; "social accountability and reflexivity"; and "quality control" (see furthermore Nowotny et al. 2001, 2003, 2006). Key in this setting is the focus on a knowledge production in contexts of application. Mode 2 expresses and

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encourages clear references to innovation and innovation models. The linear model of innovation also has become challenged by non-linear models of innovation, which are interested in drawing more direct connections between knowledge production and knowledge application, where basic research and innovation are being coupled together not in a first-then, but in an "as well as" and "parallel" (parallelized) relationship (Campbell and Carayannis 2012). Mode 2 appears also to be compatible with non-linear innovation and its ramifications.

The Triple Helix (TH) model of knowledge, innovation, and university–industry–government relations, which was introduced and developed by Henry Etzkowitz and Loet Leydesdorff (2000, pp. 111–112), asserts a basic core model for knowledge production and innovation, where three "helices" intertwine, by this creating a national innovation system. The three helices are identified by the following systems or sectors: academia (universities), industry (business), and state (government). Etzkowitz and Leydesdorff refer to "university–industry–government relations" and networks, putting a particular emphasis on "tri-lateral networks and hybrid organizations", where those helices overlap in a hybrid fashion. Etzkowitz and Leydesdorff (2000, p. 118) also explain, how, in their view, the Triple Helix model relates to Mode 2: the "Triple Helix overlay provides a model at the level of social structure for the explanation of Mode 2 as an historically emerging structure for the production of scientific knowledge, and its relation to Mode 1". More recently, Leydesdorff (2012) also introduced the notion of "N-Tuple of Helices".

Mode 1 and Mode 2 may be characterized as "knowledge paradigms" that underlie the knowledge production (to a certain extent also the knowledge application) of higher education institutions and university systems. Success or quality, in accordance with Mode 1, may be defined as: "*academic excellence, which is a comprehensive explanation of the world (and of society) on the basis of 'basic principles' or 'first principles', as is being judged by knowledge producer communities (academic communities structured according to a disciplinary framed peer review system)*". Consequently, success and quality, in accordance with Mode 2, can be defined as: "*problem-solving, which is a useful (efficient, effective) problem-solving for the world (and for society), as is being judged by knowledge producer and knowledge user communities*" (Campbell and Carayannis 2013, p. 32). A "Mode 3" university, higher education institution or higher education system would represent a type of organization or system that seeks creative ways of combining and integrating different principles of knowledge production and knowledge application (e.g., Mode 1 and Mode 2), by this encouraging diversity and heterogeneity, by this also creating creative and innovative organizational contexts for research and innovation. Mode 3 encourages the formation of "creative knowledge environments" (Hemlin et al. 2004). "Mode 3 universities", Mode 3 higher education institutions and systems, are prepared to perform "basic research in the context of application" (Campbell and Carayannis 2013, p. 34). This has furthermore qualities of non-linear innovation. Governance of higher education and governance in higher education must also be sensitive, whether a higher education institution operates on the basis of Mode 1, Mode 2, or a combination of these in Mode 3. The concept of "epistemic governance" emphasizes that the underlying knowledge paradigms of knowledge production and knowledge application are being addressed by quality assurance and quality enhancement strategies, policies, and measures (Campbell and Carayannis 2013).

Emphasizing again a more systemic perspective for the Mode 3 knowledge production, a focused conceptual definition may be as follows (Carayannis and Campbell 2012, p. 49): Mode 3 "allows and emphasizes the co-existence and co-evolution of different knowledge and innovation paradigms. In fact, a key hypothesis is: *The competitiveness and superiority of a knowledge system or the degree of advanced development of a knowledge system are highly determined by their adaptive capacity to combine and integrate different knowledge and innovation modes via co-evolution, co-specialization and co-opetition knowledge stock and flow dynamics*" (see Carayannis and Campbell 2009a, b, c; on "Co-Opetition", see Brandenburger and Nalebuff 1997). Analogies are being drawn and a co-evolution is being suggested between diversity and heterogeneity in advanced knowledge society and knowledge economy, and political pluralism in democracy (knowledge democracy), and the quality of a democracy. The "Democracy of Knowledge" refers to this overlapping relationship. As is being asserted: "The *Democracy of Knowledge*, as a concept and metaphor, highlights and underscores parallel processes between political pluralism in advanced democracy, and knowledge and innovation heterogeneity and diversity in advanced economy and society. Here, we may observe a hybrid overlapping between the *knowledge economy, knowledge society and knowledge democracy*" (Carayannis and Campbell 2012, p. 55). The "Democracy of Knowledge", therefore, is further-reaching than the earlier idea of the "Republic of Science" (Michael Polanyi 1962).

The main focus of the Triple Helix Innovation Systems Conceptual Framework concentrates on university–industry–government relations (Etzkowitz and Leydesdorff 2000). In that respect, TH represents a basic model or a core model for knowledge production and innovation application. Quadruple Helix and Quintuple Helix Innovation Systems Frameworks are designed to comprehend already and to refer to an extended complexity in knowledge production and knowledge application (innovation); thus, the analytical architecture of these models is broadly conceptualized. To use metaphoric terms, the Quadruple Helix Innovation Systems Conceptual Framework embeds and contextualizes the TH, while the Quintuple Helix embeds and contextualizes the Quadruple Helix Innovation Systems Conceptual Framework (and TH). The Quadruple Helix Innovation Systems Conceptual Framework adds as a fourth helix the "media-based and culture-based public", the "civil society", and "arts, artistic research and arts-based innovation" (Carayannis and Campbell 2009a, b, c, 2012, p. 14; see also Danilda et al. 2009). *The Quadruple Helix also could be emphasized as the perspective that specifically brings in the "dimension of democracy" or the "context of democracy" for knowledge, knowledge production, and innovation*. The Quintuple Helix Innovation Systems Conceptual Framework is even more comprehensive in its analytical and explanatory stretch and approach, adding furthermore the fifth helix (and perspective) of the "natural environments of society" (Carayannis and Campbell 2010, p. 62).

The TH is explicit in acknowledging the importance of higher education for innovation. However, it could be argued that the Triple Helix sees knowledge production and innovation in relation to economy, thus the TH models, first of all (primarily), the economy and economic activity. In that sense, the Triple Helix frames the knowledge economy. The Quadruple Helix Innovation Systems Conceptual Framework brings in the additional perspective of society (knowledge society) and of democracy (knowledge democracy). The Quadruple Helix Innovation Systems Conceptual Framework understanding emphasizes that sustainable development of and in economy (knowledge economy) requires that there is a co-evolution of knowledge economy and knowledge society and knowledge democracy. The Quadruple Helix Innovation Systems Conceptual Framework even encourages *the perspectives of knowledge society and of knowledge democracy* for supporting, promoting, and advancing knowledge production (research) and knowledge application (innovation). Furthermore, the Quadruple Helix Innovation Systems Conceptual Framework is also explicit that not only universities (higher education institutions) of the sciences, but also universities (higher education institutions) of the arts should be regarded as decisive and determining institutions for advancing next-stage innovation systems: the interdisciplinary and transdisciplinary connecting of sciences and arts creates crucial and creative combinations for promoting and supporting innovation. Here, in fact, lies one of the keys for future success. The concept and term of "social ecology" refers to "society-nature interactions" between "human society" and the "material world" (see, e.g., Fischer-Kowalski and Haberl 2007). The European Commission (2009) identified the necessary socio-ecological transition of economy and society not only as one of the great next-phase challenges, but also as an opportunity, for the further progress and advancement of knowledge economy and knowledge society. The Quintuple Helix refers to this socio-ecological transition of society, economy, and democracy; the Quintuple Helix innovation system is therefore ecologically sensitive. Quintuple Helix bases its understanding of knowledge production (research) and knowledge application (innovation) on social ecology. Environmental issues (such as global warming) represent issues of concern and of survival for humanity and human civilization. But the Quintuple Helix translates environmental and ecological issues of concern also in potential opportunities, by identifying them as possible drivers for future knowledge production and innovation (Carayannis, Barth and Campbell 2012). This, finally, defines also opportunities for the knowledge economy. "*The Quintuple Helix supports here the formation of a win-win situation between ecology, knowledge and innovation, creating synergies between economy, society and democracy*" (Carayannis et al. 2012, p. 1).

The Quadruple and Quintuple Helix Innovation Systems Conceptual Framework defines crucial benchmarks for policy and strategy that leverage knowledge and innovation for long-term sustainable development in knowledge economy, knowledge society, and knowledge democracy. These benchmarks are valid for entrepreneurs and firms, but they are also valid for public decisionmakers and governments. Furthermore, the Quadruple and Quintuple Helix Innovation Systems Conceptual Framework also brings civil society into perspective (Fig. 1.1).

1.2 Economic Growth, Public Policies, and QHI Theory

In a recent conference in Paris organized by the OECD and the World Bank, participants discussed practical means to promote innovation within the National Systems of Innovation (NSI), and public policies for promoting the interaction of universities with the private sector for the transfer of knowledge and its commercialization. They recognized Quadruple Helix Innovation Systems Conceptual Framework as an important tool for analysing the interaction between the different innovators and thinkers of the future of new industrial policies (OECD 2012, p. 3). We have chosen

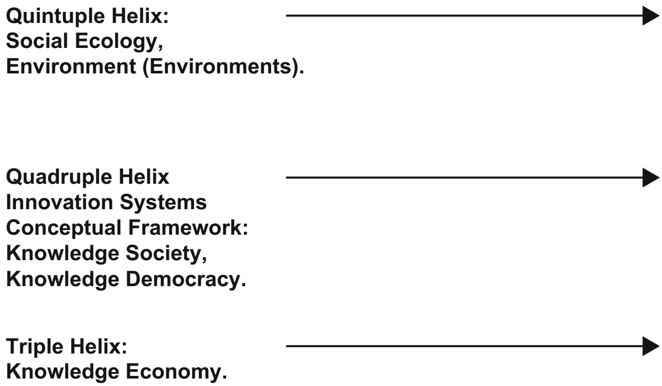

Fig. 1.1 Summarizes again visually the multi-level architecture of Quadruple and Quintuple Helix Innovation Systems Conceptual Framework (see also Carayannis and Campbell 2014) (*Source*: Authors' own conceptualization based on Carayannis and Campbell (2009c, p. 207; 2010, p. 62; 2014), Carayannis, Barth and Campbell (2012, p. 4), Etzkowitz and Leydesdorff (2000, p. 112) and Danilda et al. (2009))

this theory to illustrate the innovation economy and will build a growth model suited at this theory that can bring innovators into contact with each other and show the role of productive public expenditures in innovation and economic growth.

According to Teixeira (2013), new quantitative methodologies are needed to analyse the performance of the NSI, where innovation is increasingly systemic and the neoclassical models have failed to express new concepts and theories such as, for example, the Triple Helix (TH) Innovation Systems Conceptual Framework: "*At the very least, these competing approaches and models also addressed issues that neoclassical economics failed to consider adequately. These ' competitors' to the NSI concept included Michael Porter's Cluster's or Diamond Model of thinking, published in The Competitive Advantage of Nations in 1990, The Triple Helix model of university-industry-government interactions developed mainly by Henry Etzkowitz and Loet Leydesdorff* (1997, 2000), *and the New Production of Knowledge approach of Gibbons et al.* (1994)" (Teixeira 2013, p. 11).

The need to create new tools to measure innovation and interaction between the new innovators within the NSI is still on the agenda. As stated in the GII (2013): "[. . .] *However, innovation cannot be reduced to investments in R&D and patents. The vision offered by the GII is more complex and offers a different view about the dynamics that shape innovation globally [. . .] innovation has become more global, more dispersed than it used to be. [. . .] For* *real progress to occur at local levels of innovation, critical elements need to be explored, identified, and measured. These elements include the specific strengths and weaknesses of local industries and knowledge institutions as well as access to finance and to markets within and outside national borders.*"

Regarding public policies, we believe these policies must be adapted to specific contexts and be dependent on trajectories or growth paths, without replicating successful models. In this regard, the OECD (2011) report offers the following idea: "*[...] Firms, organisations and Institutions, as well their interactions, differ substantially across countries. This implies that policy responses to systemic imperfections will be country specific. Differences in historical Institutional settings explain country-specific paths of development and innovation climates*" (OECD 2011, p. 230). An optimal level of coordination and effectiveness is needed between the different economic policies, which should be analysed and taken into consideration as a whole, in line with the OECD report: "*design a smart policy mix, asset-based and multi-sector, aligned with regional strategy, would integrate several policy fields, vertically and horizontally, strengthen synergies across levels of government, horizontal collaborations of public and private stakeholders for increasing policy impact*" (OECD 2011, p. 89).

Being aware of these realities as we undertake this book, *we wish to stress the importance of investments* in innovation as a means to increase the development of productivity in OECD countries in close coordination with a smart mix of policies, and with country-specific science and technology programmes, but bearing in mind that the entire civil society is now involved in the innovation process. We will develop a growth model based on the "QH" Innovation Systems Conceptual Framework linking four pillars or innovators (the State, the companies/industry, the academia, and the technological infrastructures and social society) to analyse their joint impact on economic growth (Carayannis and Campbell 2009b).

The model we will build and subsequently present contains a second scientific contribution in terms of theory. It is in fact an innovation growth model based on productive public spending, which, according to Irmen and Kuehnel (2009), is new to the literature on public spending and economic growth.

Following a *bibliographical review of the endogenous economic growth models*, we will retain the specifications of Thompson (2008) that are based on the model of multiple equilibria of Evans, Honkapohja, and Romer (1998) with complementarities between capital goods in the production function, taking a single sector as in Rivera-Batiz and Romer (1991), in which the same technology is used for consumption, investment in physical capital and in the production of new designs, and with a single "steady state" type of equilibrium. We have chosen this model because the concept of complementarity (Matsuyama 1995) seems to be perfect for illustrating this new innovation economy, where everyone benefits from the interaction, cooperation, and the sharing of knowledge. Therefore, and according to Thompson (2008), we assume that there are complementarities between all the entities that contribute at an intermediate level to the production of a final product—technological infrastructures, the academy, and companies, which we will call Intermediate Production Units.

As regards the introduction of productive government spending in the endogenous growth theory, we will refer to the work of Romer (1990a, b); Irmen and Kuehnel (2009) for the models presented. In his article entitled "*Government Spending in a Simple Model of Endogenous Growth*", Romer (1990a, b) introduced the public sector in the endogenous growth model on one hand, to track the externalities associated to productive government spending and to taxes on the other hand, to successfully assess the effects of public policy decisions on economic growth.

Irmen and Kuehnel (2009) critically reviewed recent literature that introduces the variable "productive government spending" to the theory on endogenous economic growth (in which changes in tax policy parameters must have a long-term effect on growth). According to the authors, this literature is very important in the future as it assesses the quality of public policy recommendations.

Since the studies by Aschauer (1989) and then Romp and Haan (2007), it is commonly accepted that the growth of the government's productive activities increases the output. Easterly and Rebelo (1993) have also found long-term effects associated with public investments in infrastructures. However, the first article that introduces government spending as a public asset in the utility function of individual firms is pinned on Barro (1990a).

Barro (1990a) showed that government activities are also a source of endogenous growth; for that reason, the author assumes that the government purchases a part of the private production and provides free public services to private producers, and the private production purchased by the government concerns non-competitive and non-exclusive goods.

Irmen and Kuehnel (2009) add to Barro's model (1990a, b) components to assess the effects of public services on economic growth. According to the authors, to study the result of each component introduced, the corresponding Euler equation must be analysed to successfully characterize the determinants of the equilibrium growth rate, and understand the role of the tax policy measures on the growth rate.

While Barro (1990a) incorporates in his analysis the productive government spending as a flow variable, Futagami et al. (1993) introduced a provision of government services as a stock variable, which seems to be more realistic. On the other hand, however, this creates a complex analysis, because we obtain both a very complex transient dynamics and a stationary equilibrium growth rate that cannot be obtained through the Euler equation.

a fixed ratio to per capita?

Irmen and Kuehnel (2009) present an analytical framework in which government activities are needed to balance the per capita variables. In this framework, these activities are treated as flow and stock, and in both situations the authors reach the same conclusions:

(i) in the case of individual firms, the performance of private capital is constant and the services result from the government's productive activity;
(ii) from a social perspective, two assumptions lead to an asymptotically linear production function of firms. According to the first assumption, the services provided to firms are proportional to the overall level of government activity; as for the second assumption, the current flow of public spending is proportional to the size of the economy. Therefore, the features of the stationary government for all the scenarios are the same in the AK models, where the Euler equations determine the stationary equilibrium growth rate, which is important for comparing the links between government productive activity, economic growth, and well-being;
(iii) the impact of productive government spending on the stationary equilibrium growth rate of consumption through a direct effect on technology, and an indirect effect on the investment subsidies is always positive, with the exception of the "small open economies" in which the consumption growth rate is determined by factors external to the domestic economy.

The NSI approach points out the fact that the technology and information flows between people, companies, and institutions are the key to the innovation process; the interaction between the different players in this process, between the users and producers of intermediate goods, and between companies and universities is essential to innovation (Morgan 1997; Lagendijk and Charles 1999), and the innovation process depends on the institutions, which are sets of habits, routines, established practices, rules or laws governing the interactions between individuals, groups, and organizations (Edquist and Johnson 1997).

This approach places innovation and learning processes at the centre of the analysis, and it is this focus that distinguishes the NSI approach from others that consider technical changes and innovation as exogenous variables; it adopts a holistic and interdisciplinary perspective, which allows for the inclusion of organizational, social, and political measures, integrates a historical and evolutionary vision, and stresses the interdependence and non-linear characteristics of innovation; this approach may include product innovation, intangible processes and services, and even the role of institutions.

The performance of countries in terms of innovation depends on how the different players relate to each other as elements of a collective and complex system, how they develop knowledge within a set of activities that determine the technological learning rate in a country. According to the OECD (1999), the links between the different players may take the form of joint research, staff exchanges, cross-patents, purchase of equipment, and other channels. To construct indicators necessary to understand the different types of knowledge flows, the OECD is committed to identifying institutional links, human resource flows, industrial clusters, and innovative companies; however, as we have seen, this item is on the agenda for future research.

There are, nevertheless, other empirical methods for studying the NSI: for example, the method used by Lundvall (2007), who shifts the analysis from micro to macro, and back to micro again. His model begins with stylized facts and looks at what takes place within the companies. Then, the author analyses the interaction between companies to explain the differences between and within countries on account of the specificities of each country's education system, labour markets, financial markets, and social and intellectual protection schemes. The author then re-examines the companies and networks to explain the specialization, competitiveness, and performance growth of an economy.

Most existing studies on the NSI based on international benchmarks analyse the country-specific education systems, labour markets, financial markets, and intellectual property schemes (Balzat and Hanusch 2004).

Based on the taxonomy of empirical research on the NSI, "*policy-oriented*" studies exist to identify the best practices, but they lack a systemic vision, such as, for example, the studies by Eichhorst et al. (2001), Polt et al. (2001) and the OECD (1998); there are other studies—"*research oriented*"—on developed countries that use innovation indicators and index numbers (descriptive and analytical models that give the NSI concept an operational dimension), such as, for example, the studies by Liu and White (2001), and Porter and Stern (2002). Regarding middle-income countries, some analyses evaluate the relevance of the NSI concept, such as the analysis by Freeman (1999).

Freeman (1995, 2000) and Lundvall (2006) identify many potential avenues for developing and deepening the NSI approach, for example, a clearer and more explicit combination of the NSI approach and of economic growth. This also seems to be the idea expressed by Teixeira (2013). In this sense, the "National Innovative Capacity" model by Furman et al. (2002) is regarded as one of the important pillars of the NSI analyses because this approach acts as a bridge between the endogenous growth theory and the approach to the systemic vision of innovation.

In keeping with Sornn-Friese (2000), future research work on the NSI should be more concerned with the identification of the institutions that positively influence innovation and economic performance. Systems thinking based on the NSI leads to a different view of how governments can stimulate a country's performance and innovation (Nelson and Romer 1996; De Liso 2006; Shariff 2006; Kline and Rosenberg 1986; Groenewegen Steen 2006; Lundvall 2007), where companies, universities, and other public research bodies are involved in education, training, science, and technology. Studies on the NSI show that the public research sector can be more important as an indirect source of knowledge production than as a direct source in scientific and technical breakthroughs.

Public policies under the NSI approach are necessary to overcome system failures, and these policies promote research (emphasizing the role of joint research activities, research and technology schemes in partnership with the government, cross-patents, co-publications, and human resource mobility, implementing intellectual property rules, market and labour policies, and technological infrastructures) and the improvement of corporate capacity in terms of their absorption capacity.

Interventions in terms of NSI public policies may be regarded as different ways of encouraging interactive learning between the sub-systems. Thus, public activity is justified to overcome the imperfect innovation system when the essential elements in the system are inexistent, or when those links and the knowledge flows fail to work.

We have chosen the new Quadruple Helix Innovation Systems Conceptual Framework because it describes a new economic reality within the NSI, where innovation is considered as the result of the co-creation between companies, citizens, universities, and the government, against a background characterized by the existence of partnerships, collaboration networks, and symbiotic relations. The economic structure of a country is based on four pillars—the academy and technology infrastructures, on one hand, the companies, the government and, finally, the civil society, on the other hand—and economic growth is managed by the establishment of differentiated productive units interacting and complementing each other to continuously innovate (Carayannis and Campbell 2006, 2009a, b; Arnkil et al. 2010; MacGregor et al. 2010a, b).

Subsequently, we will develop a model that links these four pillars and explore, at an analytical level, their interactions and joint impact on economic growth.

We will establish a new "bridge" between the theories of endogenous growth and the systemic view of innovation presented by the Quadruple Helix Innovation Systems Conceptual Framework and we also test our Quadruple Helix Innovation Systems Conceptual Framework and main predictions with the help of non-stationary panel econometric methodologies. The study of "innovation systems" offers a new perspective on public policies. The purpose of most technology and innovation policies emanated from the government is to correct market flaws. This new approach should draw the attention of policy makers to systemic flaws, which may include, for example, the lack of interaction between system innovators, poor coordination between basic research and the public sector, or difficulties in transferring knowledge to the industry. New policies are, therefore, suggested to improve network capacity, their object being joint research activities and other kind of collaboration work, and schemes to promote research and development (R&D) in advanced technologies in partnership with the government. These new policies give prominence to cross-patents, co-publications, social mobility, implementation of intellectual property rules, labour market rules, and collaboration work.

By highlighting the role of economies of scale and externalities, endogenous growth provides for the possibility of considering the effects of public policies.

We present a reflection on the new approach to public policies within the NSI:

In general, and according to Amable and Guellec (1992), an effective public policy should subsidize the growth factors subject to increasing economies of scale and positive externalities. Similarly, the State will even have an equally less negative impact on growth in that it does not limit withholdings to the factors that do not generate externalities.

The provision of technological infrastructures, the contributions to the qualification of human capital, and the guarantee of property rights should be the responsibility of the State, or at least be under its control, because it is not possible to prevent their use by private agents, because the private yield they offer is less than the social yield, or even because they cannot be financed by the agents in question despite their interest.

In the models shown, we have a pure public good, in other words, the supplier cannot stop an agent from using it freely, and one agent's use does not preclude its use by another. Each agent benefits from all the public spending because the effect is indivisible between agents. The finding from the model is that investments and public services contribute enormously to growth, and that is consistent with the work of Aschauer (1989), who concluded that the slackening of public investments in the 1970s until the mid-1980s in the OECD countries was one of the causes of the productivity slowdown.

According to Romer and Nelson (1996), major public policy decisions are usually made in times of crisis and uncertainty, along with renewed science and technology policies, and changes in the economic role of the university. We agree with these authors that the details of the science and technology policy must be adapted to the circumstances but, in our opinion, we should not change the principles. We are increasingly seeing that safety and health have lost their ground to new domains defined in each period as having economic and commercial opportunities for a specific country, and where the State is required to play a role; the universities should maintain their role in the production of basic knowledge and should also have advanced programmes to provide training to the human capital working in the industry but they have also a more active role in market through patenting. Empirical studies conducted in many countries also show that the industry needs to keep close contact with the research done at the university so that innovation can be successful (see, e.g., Faulkner and Senker (1995); Mansfield et al. (1997); Mansfield (1980)). We must therefore create more interaction mechanisms between universities and the industry.

Many industrialized countries have since 1980 implemented public policies to strengthen the links between the university and the industry, policies to support the creation of clusters and university spin-offs, and policies to support the issue of patents. These policies are referred to in literature as "public technology commercialisation policies" (cf. Mowery and Sampat (2005), p. 225) and characterize the emergence of technological clusters due to a certain contingency, a dependent pathway, and to policies that promote links between the university and the industry.

Current structural policies emphasize the cooperation between the different players. With the literature on the national innovation systems, the

"Mode 2 and 3" of knowledge production, and the TH and QH models, the role of universities and the links between all the innovators appear to be calling for cooperation, coordination, and competition among them. The TH model brings a new approach to the innovation policy, that of collaboration among the institutional spheres. At this level, it should be considered as the result of a cumulative process resulting from the interaction of government at different levels with the academia, the industry, and other non-governmental organizations (Etzkowitz 1988, 2003; Leydesdorff and Meyer 2006). However, according to Yawson (2009), a fourth pillar or strand is missing in the TH model: the public sphere. According to the author, this fourth strand becomes crucial as scientific knowledge is increasingly more evaluated by its social robustness and exclusivity. The emphasis of this fourth pillar is on innovation in order to achieve social well-being, such as, for example, eco-innovation, and it helps create links between science, scientists, and education strategies. As stated by Liljemark (2004), this fourth pillar will provide the links between the different TH model strands. Yawson (2009) calls this fourth strand of organizations "innovation facilitators". These developments have presented the civil society and the State as the users of the innovation produced in universities, in addition to companies and industries. Because of this, decentralized, horizontal, and functional innovation policies are beginning to emerge. This new vision highlights the "user-oriented" innovation: users and communities of users play an increasingly important role in the successful innovation (Edquist and Hommen 2009).

While public policies in support of "user-driven" innovations are just starting, we believe that major coordination between the various public policies needs to be more oriented to economic benefits, and also to society.

Three aspects need to be considered simultaneously to identify the outlines of a new policy: the institutional perspective, the innovation systems, and the strategic choices of regions and countries with a view to their transition to knowledge and innovation economies. The combination of these three aspects increases the complexity of policies at all government levels, but it is nevertheless of vital importance to achieve the objectives assigned to these policies.

To develop a *smart mix* of more sophisticated policies, we need to:

(i) develop a vision and a strategic approach to encourage innovation. To manage change, it is necessary to move towards outcome-oriented policies, based on an innovation-oriented regional development strategy, either building on current benefits (based on science, technology, or both), or acting towards social-economic transformation (reconversion or research for new specializations), or even carry out a remedial exercise (improve the potential for creating knowledge and absorption capacities). So, an important first step is to clarify the major issues as part of an overall vision, and to change them into measurable objectives;

(ii) define a "smart" portfolio of policies (multi-sector and based on assets). A portfolio of policies consistent with the regional strategy should include different policy areas. The portfolio of instruments originates from various government levels. The OECD survey on the multi-level governance of the innovation policy shows that the regional and national governments (apparently) use similar instruments and that, therefore, the search for synergies between instruments of different government levels is required to ensure the impact of policies;

(iii) a complementary set of instruments should be oriented towards defining the functions of creation, dissemination, and absorption of knowledge, and combine traditional (e.g., human capital), emerging (e.g., the new generation of science and technology parks, or support to creativity), and experimental instruments (e.g., public procurements). Their performance should be assessed individually and jointly;

(iv) establish multi-level open and network governance structures. The combination of these decentralization phenomena, of region-specific initiatives, and the increasing attention paid to territorial dimensions in national policies generate an increased mutual dependence between levels of government in terms of innovation policy;

(v) the development of effective coordination mechanisms for the vertical coordination between government levels. Coordination tools should be created based on the diagnosis of major multi-level governance issues. In the OECD survey, most countries are reported to use multiple mechanisms (dialogue, consultation, contracts, co-financing of projects, regional development agencies, and territorial representatives). The mechanisms that strengthen the dialogue are seen as the most effective. Based on this dialogue, senior-level financers can define cross-compliance systems to be associated to a "smart" policy portfolio;

(vi) the horizontal collaboration between public and private actors should be strengthened. The tools used in this multi-actor and multi-sector coordination are as follows: interdepartmental commissions, high-level strategic advice, regional innovation agencies;

(vii) functional regions should be addressed by the policies. Administrative boundaries introduce a bias because they are inconsistent with the existing networks and functional relations beyond those boundaries. The policies should be open to national and international relations. Regional networks (clusters, innovation systems) should have links with global networks;

(viii) develop policy learning by implementing better measurement and evaluation techniques, and through experimentation. The regions can play a major role in improving the quality of empirical elements available, and introducing efficient monitoring and evaluation mechanisms;

(ix) develop new indicators to measure both the innovation linked to R&D and innovation without R&D, providing a picture of the networks within and outside the region, and to quantify private and public innovation support efforts. To understand the different innovation profiles of regions, comparative data and policy analysis techniques are needed. Evaluations should be more robust and should not only discuss inputs but also focus on results, impacts, and changes in the behaviour of companies and innovators;

(x) regions can be good laboratory ground for the innovation policy. The diversity of regional situations and the unpredictable nature of the innovation process drive the need for experimenting with policies. Pragmatic experiments that can inform national policies should be accompanied by policy evaluations focused on results.

1.3 Coordination Level Between Public Policies: Is It Necessary?

In the systemic vision of innovation, there is a need to analyse the input of the various innovation policies and to review the links between the different players in the system; the goals of these policies are economic growth, competitiveness, and social cohesion (Edquist and McKelvey 2000). Every country implements some coordination among a mix of public policies, but this mix differs from country to country. For example, Japan uses its national policy to promote strategic sectors and specific industries, but the private sector is the most represented in R&D funding; moreover, the modernization of traditional sectors plays an important role in the economy. In its third report "*Science and Technology Basic Plan* (2006–2010)", Japan states the priorities in some sectors and the need to reorganize its "innovation ecosystem", including its technological infrastructures to successfully pull the economy out of stagnation. In this respect, Japan calls for a new vision of science and technology in their relation with civil society. In the USA, policies are organized in relation to the complex industrial systems with relevant federal R&D investment, the strengthening of the role of National Aeronautics and Space Administration (NASA) in technological development, and prioritizing the orientation of public policies towards the creation of technological infrastructures. In Europe, we have a significant diversity of realities called "European paradoxes" and a variety of knowledge policies; it is here that the need for an integrated vision of public and private policies is felt most, in order to successfully achieve competitive markets and efficient tax frameworks to promote innovation, in which public-private partnerships, technological infrastructures, knowledge and technology hubs, clusters, and researchers-entrepreneurs play an important role.

We can conclude that, according to Lundvall and Borrás (2005), if innovation is a "path-dependent" and "context-dependent" cumulative process, public policies should be defined according to context. They should be robust, flexible, include diversities and complementarities of the "innovation systems", and should be improved through a cumulative process. New policies should be implemented through "pilot-projects" before being disseminated across the economy. The coordination with other national and international policies is important in terms of emerging technologies owing to the involvement of the civil society in innovation and technology to successfully achieve an inclusive growth.

In the next point we can find evidence from this.

1.4 Overview of National STI Plan or Public Strategy

Based on OECD science, technology and industry (STI) outlook 2014 we present the following summary of STI strategies or national plans:

Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
Australia	AUD 100 million growth fund + Research workforce strategy+ National Industry Investment and Competitiveness Agenda	Support initiatives in regions facing pressure in their manufacturing sectors, offer a vision for 2020 of a strong and productive Australian research workforce with skills to support innovation, promote national competitiveness and productivity to encourage innovation, support for R&D, and the commercialization of good ideas.	Encouraging innovation in firms and support entrepreneurship—invest USD 329 million in a new entrepreneurs infrastructure programme with AUS industry; Government aims to improve productivity and job growth by cutting the costs of red tape for business and community groups by USD 680 million; The Australian government is providing USD 102 million in 2014–2015 to secure Australian researchers access to current major facilities.
Austria	Becoming an innovation leader	With the main objective to be one of the EU's most innovative countries by 2020 and among the innovation leaders they focus on: (i) a well-equipped education system; (ii) basic research; (iii) intensified R&D activities in companies ensured by knowledge transfer between scientists and businesses; (iv) new funding governance structures and a multi-level political system from coordination to internationalization.	Raise R&D expenditures to 3.76 % of GDP by 2020; Strengthening science-industry-knowledge transfer linkages, using innovation to address social challenges, strengthening public R&D capacity and infrastructure, Austria takes an active part in European Forum on ESFRI, increase research- intensive firms by 3 % a year and firms conducting R&D by 25 % by 2020. The R&D premium (fiscal instrument) was raised from 8 % to 10 % to reach USD 691 million in 2012. A "manufacturing of future" initiative has a budget of USD 70–80 million to strengthen Austrian manufacturing

(*continued*)

Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
			through research on future technologies and processes. Biotechnology action plan with a budget of USD 60 million during 2013–2015. GERD was 2.86 % of GDP in 2013 and has the objective to spend 2 % of GDP on higher education by 2020, and to raise GERD to 3.76 % of GDP by 2020 with up to 70 % funded by business.
Belgium	Different strategies with different objectives in Federal Government, Brussels Capital, Flanders and Wallonia	For example, Creative Wallonia Action plan intends to put creativity and innovation at the hearth of economy and society; Also the Pact 2020 and the foresight study at Flanders is very central in societal challenges and the smart specialization strategy in Brussels Capital intends to identify sectors in which the region will invest.	The main objectives of the several policies are: Raise R&D expenditures to 3 % of GDP by 2020; raise education investment to 2 % of GDP by 2020; encourage partnerships for research and optimize tools for exploiting research results, increase number of people involved in awareness initiatives for S&T professions, increase number of companies active in European research programmes; transformation the economy by innovation; priority sectors: ICT, life sciences and environment. The federal government has increased the reduction on the advance tax payment for all research and technical staff in young innovative firms from 50 % to 75 %. The Walloon government's overall budget for direct support of business R&D and innovation increased by more than 70 % over the last 5 years to USD 144 million in 2013.

Canada	Mobilizing science and technology to Canada's advantage	Promote world-class excellence, foster partnerships, and enhance accountability.	Clusters and smart specialization: open data with USD366 million and USD 180 million euros to the world's largest cyclotron particle accelerator. Canada spends the highest share of GDP on higher education in OECD area and has a strong skills base in science and innovation. USD 183 million to the global health challenge.
China	Medium- and long-term national plan for S&T development and 12th Five-year plan for S&T development	Innovation to restructure Chinese industry, improve indigenous innovation capability in firms, strengthen competitiveness and international influence with a focus on people, creativity, and innovation, better S&T governance systems and better coordination and collaboration among stakeholders.	Raise R&D expenditures to 2.2 % of GDP; raise the share of citizens with basic scientific proficiency to over 5 %; raise the number of researchers to 43 out of every 10,000 employees; raise Investment of industrial companies in R&D to an average of 1.5 % of their revenue; increase the role of enterprise in driving technological innovation. China's R&D intensity has tripled since 1998 reaching 1.98 % of GDP in 2012 and approaching the level of EU28. Firm self-funded R&D reached 95 % of BERD in 2012.
Czech Republic	National Innovation Strategy and International competitiveness strategy	Excellent research; cooperation between research institutions and enterprises; innovative entrepreneurship; civil society as originators of new ideas and initiators of changes. Nine pillars to strengthen the competitiveness: institutions, infrastructures, macroeconomics, health care, education, labour and financial markets, business and innovation environment.	Raise R&D expenditures to 2.7 % of GDP by 2020 and raise government spending on R&D to 1 % of GDP by 2020. The share of industry-funded GERD dropped from 47.2 % to 36.4 %, and government-funded GERD from 44.7 % to 36.8 %.

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Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
Denmark	The innovation strategy, Denmark a nation of solutions and Research 2020	A more demand-driven innovation policy; find the most promising research areas for growth, employment and welfare using societal challenges as starting point. A nation of solutions focuses on better knowledge exchange between companies and knowledge institutions, between public and private sectors.	Raise R&D expenditures to 3 % of GDP; 95 % of a youth cohort to complete an upper-secondary education programme; 60 % a higher education programme and 25 % a long-cycle higher education programme.
Estonia	Knowledge-based Estonia, entrepreneurship strategy	Create favourable conditions for increased productivity and standard of living, good education and culture; single strategic framework to ensure coherence of entrepreneurial and innovation policies.	Raise R&D expenditures to 3 % of GDP and Raise business expenditures on R&D to 2 % of GDP. The government is committed to stimulate business R&D and innovation through direct funding and non-financial measures with USD 255 million over 2014–2020. One of the fastest increases in GERD in the OECD area.
Finland	Action Plan for Research and Innovation Policy and Internationalization of Education, Research and Innovation (ERI)	More efficient use of research outcomes and strengthen the social impact of STI policy; ensure long-term basic funding for universities and public research institutions; use research funding more strategically to boost the exploitation and social impact of research outcomes. Create and maintain infrastructures; promote networking and risk-taking; speed up the internationalization of PRIs and enterprises. The Witty City Programme supports collaborative projects between business, municipalities and	Maintain R&D intensity at 4 % of GDP to 2020 (public R&D funding at 1.2 %). All human capital indicators for Finland are above the OECD medians.

		research organizations to provide companies with opportunities and bring to market new products and services.	
France	National Research Strategy, plans for industrial recovery, innovation 2030, National Strategy for Higher Education, a new deal for innovation	Identify 10 societal challenges and define a research strategy for each one; identify 34 plans to define innovation-focused strategies for industrial sectors and development of sectoral contracts in partnership with entrepreneurs; define major innovations to meet needs of tomorrow's society; organizing and evaluating public policies for innovation; developing a culture of entrepreneurship and innovation; increasing economic impact of public research through transfer; supporting business growth through innovation, large venture fund.	Raise R&D expenditures to 3 % of GDP by 2020.
Germany	High-Tech Strategy and extension	Identify Key technologies to support emergent markets, societal innovations to transform research results better and faster into practice. Germany has a strong science base and high public spending on R&D; German industry and science has also strong links and a very high proportion of public research is funded by industry.	Raise R&D expenditures to 3 % of GDP by 2020. Germany spent 2.98 % of GDP on R&D in 2012, public expenditure on R&D AT 0.96 % of GDP and business expenditure on R&D at 2.02 % of GDP.
Greece	Strategic Plan for Research, Technology and Innovation	Replace the existing legal framework in order to address emerging STI policy issues and long-term challenges in Greece; establish more favourable conditions for R&D&I and the exploitation of new	Raise R&D expenditures to 1.5 % of GDP by 2020.

(*continued*)

Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
		knowledge; a variety of incentives to promote investments by the private sector; link research with industry; support research infrastructures; increase dissemination of research results on all issues related to science in society to generate economic and social value.	
Hungary	National Research and Development and Innovation Strategy—Investment in the Future	Focus on utilization-oriented R&D and innovation activities of companies and the public sector utilizing the results of modern science and technology.	Raise R&D expenditures to 1.8 % of GDP and raise business expenditures on R&D to 1.2 % of GDP. Weak collaboration culture a barrier to better coordination of national innovation policy.
Iceland	New Policy for Science and Technology	Focused on education system with emphasis on the natural sciences and technology, cooperation and efficiency, growth and value creation, monitoring results. Iceland has a strong science base and remains at the OECD median in terms of business R&D intensity.	Raise R&D expenditures to 3 % of GDP by 2016.
Ireland	Strategy for Science, Technology and Innovation	Improve competitiveness, remain attractive to FDI, maximize social cohesion, and promote R&D as an innovation-driven economy. Ireland has a large number of top corporate R&D investors.	Raise R&D expenditures to 2.5 % of GNP by 2013.
Italy	National Research Plan, Industry 2015, Strategy for the internationalization of Italian research, destination Italy	Based on Major Societal Challenges in H2020, promoting knowledge-driven research, strengthen the involvement of the business sector and cooperation with public	Raise R&D for 1.53 % of GNP by 2020.

		sector, support internationalization of research, concentrate effort on large projects and research infrastructures enhance the competitiveness of the productive system through industrial innovation projects and research infrastructures; identify research infrastructures of excellence.	
Japan	Comprehensive strategy on science, technology and innovation, 4th S&T Basic Plan	Design Japan's ideal economic society from the viewpoint of STI policies; policies to address societal challenges, realization of a policy to be created and promoted with civil society, focus on the roles of human resources and organization.	Raise R&D to 4 % of GDP by 2020 but public R&D expenditure is modest especially in light of Japan's High GERD intensity. Japan's business sector is one of the world's most R&D intensive 2.57 % of GDP in 2012. In 2012 created the programme for creating start-ups from advanced research and technology with USD191 million.
Netherlands	Enterprise Policy "to the TOP" and Strategic agenda for Higher Education, research and science	Make Netherlands one of the top five knowledge economies in world by 2020, by better utilization of the knowledge infrastructure by the business sector, strengthen the quality of education, focus on specific economic sectors, strengthen research through promotion of cooperation in the golden triangle, education, research and entrepreneurship.	Raise R&D expenditures to 2.5 % of GDP by 2020 and establish a top consortia for knowledge and innovation to which public and private parties contribute and 40 % should be financed by business sector. The Netherlands ranks among the top countries on the OECD ease of entrepreneurship index.
New Zealand	Business Growth Agenda	A more competitive economy based on export markets, innovation, infrastructures, natural resources and capital markets, boosting public investment in science and	Raise business R&D expenditures to more than 1 % of GDP Increase the rate of exports to GDP from 30 % to 40 % by 2025. The government has recently made a number of significant

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Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
		innovation, developing innovation infrastructures.	investments in public science and research USD 91.4 million over four years; strong angel investment market and a weak venture capital industry
Norway	Political platform, white paper on research, on intellectual property rights, on the organization of innovation, on innovation policy	High priority for knowledge, innovation and technology, establishment national seed capital funds, identify priorities for research cooperation through H2020.	Raise R&D expenditures to 3 % of GDP.
Poland	Dynamic Poland 2020, science strategy	Adjust the regulatory and financial environment to innovation needs; promote the drivers of a knowledge-based economy, such as biotechnology, nanotechnology, materials and ICT; support clusters development.	Raise R&D expenditures to 1.7 % of GDP by 2020; Raise S&T expenditures to 1.7 % of GDP by 2015 Raise allocation to science to 1 % of GDP.
Portugal	Research and innovation strategy	Multi-level research and innovation strategy.	Raise R&D expenditures to 3 % of GDP by 2020. Lacks a tradition of linking scientific research with innovation and industry-financed public R&D is one of the lowest among OECD countries.
Slovak Republic	Research and innovation strategy for smart specialization, RIS3	Integrate key industries through cooperation of local supply chains in clusters, increasing the contribution of research to economic growth, create a dynamic and inclusive society, improve quality of HR.	Raise R&D expenditures to 1.2 % of GDP by 2020.

Slovenia	Research and Innovation Strategy, research infrastructure roadmap	Establish a modern research and innovation system, better link science to business needs and capabilities, more public funding of innovation-oriented R&D, implementation of the national roadmap for research infrastructure, public awareness of the impact of industrial R&D activities.	Raise R&D expenditures to 3 % of GDP by 2020 and special measures to promote business R&D investment.
Spain	Spanish strategy for science, technology and innovation	Long-term STI policy and approaches to maximize economic and social benefits. Service to society as a driven force behind S&T advances and need to accelerate the flow of research and knowledge in economy. Spanish PRIs and universities are quite active in patenting but the challenge is to enhance the contribution of public research to the economy and society.	Raise R&D expenditures to 2 % of GDP by 2020.
Switzerland	ERI-Dispatch	Focus on education, research and innovation, on principles of equal opportunity.	Raise Educational attainment to at least 95 % of youth at upper-secondary level education.
UK	UK Industrial strategy	Identify areas of competitive advantage to the next 20 years Government commitment and to a long-term partnership with business sector. And strengthen UK ability to accelerate the commercialization of emerging technologies.	USD 879 million government investment in 8 cross-platform emerging technologies; USD 115 million in the global collaborative space programme; USD 108 million annually invested to improve research and innovation capacity of emerging countries and to build research partnerships with the UK.

(*continued*)

Country	*National STI Plan or Public Strategy*	*Main Priorities*	*Indicators*
USA	Strategy for American innovation	Building blocks of American innovation, R&D, human, physical, and technological capital.	Raise R&D expenditures to 3 % of GDP. The 2014 federal budget invests USD 2.9 billion to create high-quality manufacturing jobs, expand R&D on innovative manufacturing processes, advanced industrial materials and robotics, encourage entrepreneurship, and improve the transition from discovery to the market place.
EU28	Innovation Union Flagship Initiative	Ensure Europe's global competitiveness to a smart, sustainable, and inclusive growth and jobs creation; strategic use of public procurement for innovation, industrial leadership, meeting societal challenges.	Raise R&D expenditures to 3 % of GDP by 2020.

1.5 Overview of the Book

Our book has the aim of defining the impact generated by the productive public expenditures and public policies on innovation and economic growth in the countries of the OECD. We will draw inspiration from the Quadruple Helix (QH) Innovation Systems Conceptual Framework in order to construct a theoretical model of economic growth that will assess the role played by Governments in "innovation ecosystems", in the presence of innovation open systems and the "Mode 3" of knowledge production.

We chose the recent Quadruple Helix Innovation Systems Conceptual Framework on NSI as it describes a new economic reality where innovation is seen as the result of co-creation between businesses, citizens, universities, and government, in a context characterized by the existence of partnerships, networks of collaboration, and symbiotic relationships. This is a development relative to the "Triple Helix" (TH) Innovation Systems Conceptual Framework, according to which the interaction between universities, government, and industry is the source of new knowledge, technologies, or products and services that are made to serve the needs of society (Etzkowitz and Leydesdorff 2000; Etzkowitz and Klofsten 2005). To this a fourth helix in the innovation system is added: civil society. Thus, we arrive at the Quadruple Helix Innovation Systems Conceptual Framework (Liljemark 2004; Khan and Al-Ansari 2005).

According to the Quadruple Helix Innovation Systems Conceptual Framework, the economic structure of a country is based on a Quadruple Helix Innovation Systems Conceptual Framework—on one side, the academy, on the other side, companies, the government, and finally, civil society. Economic growth is managed by the creation of differentiated productive units that interact with each other and complement each other in the production of continuous innovation (Carayannis and Campbell 2006, 2009a, b; Arnkil et al. 2010; MacGregor et al. 2010a, b).

A theoretical model of economic growth will be developed to demonstrate the importance of Governments in promoting innovation, and ultimately its contribution to economic growth. This will make it possible to evaluate the effects of productive public spending through a study of "transitional dynamics" and an empirical analysis based on the database CANA (2011).

The strategy has two main areas of focus:

(a) The theoretical model of economic growth built, our smart growth model, with productive public spending, to illustrate the theory (QH) based on the concept of the interaction of four strands of a helix: the academy, companies and industry, government, and civil society. The objective is to understand the true interaction among these four strands, and therefore among the innovation actors on growth, as well as to assess the effects of productive public spending through a study of "transitional dynamics".

(b) In Chap. 3 will be built an empirical model to test the theoretical model on a sample of 23 countries of the OECD for the period 1980–2008 using the data base CANA (2011) and the RATS software. Specifically, the authors estimate the production function model and with the help of non-stationary panel techniques, they regress long-run as well as short-run equations, the latter accounting for transitional dynamics aiming to confirm co-integration relationships; to test for weak endogeneity and for causality in the short run by using panel ECM equations; finally, special emphasis is given to the role played by political-institutional and social capital variables. Our results confirm the main theoretical model predictions including the role played by Governments on NSI for the sample chosen.

Indeed, the performances of national technology innovation plans are dependent on public policy guidelines and, at the same time, on the organizational capacity of technological innovation actors. Therefore, it is necessary to devote a focus to public policy by questioning what should be the optimal level of coordination between the various policies, including the "smart policy mix".

(c) In Chap. 4 policy makers and stakeholders can find a proposed approach to understand how innovation policies are constructed, what rationales, targets and mix of instruments to consider. This can be helpful in the development of the recent regional-based smart specialization strategies and entrepreneurial discovery processes.
(d) Chapter 5 seeks to address the gap between discourse and practice regarding the fourth helix in smart specialization strategies. This chapter strives to shed light on the current debate on regional governance. We can find a case study of a particular regional setting (the Region of Aveiro in Portugal) and the process that led to the definition of its Territorial Development Strategy for 2014–2020.
(e) The aim of the research contained in Chap. 6, is to explore how regional stakeholders can improve local and regional innovation policies and the transfer of best practices by devising a technique

that ranks the EU innovation Scoreboard indicators and instructs which indicator, if improved, could have the greatest impact for the region. Regional stakeholders can utilize the approach adopted to understand what innovation indicator from the innovation scoreboard they should select in order to deliver the greatest impact for the efforts. The tool can be supportive in the development of regional-based smart specializations and regional development policy.

(f) Chapter 7 presents a long overview about innovation evaluation and measurement at macro and firm level.

(g) Chapter 8 in the context of *Smart Cities* analyses the collaborative dynamics within the smart city arena in Portugal, stressing the role played by the helices of the Quadruple Helix Innovation Systems Conceptual Framework. The innovation process is analysed at urban level, being oriented to the co-creation of creative solutions to solve urban problems and to answer to the city's future challenges.

(h) The n-Helix literature provides a basis for considering intermediate structures where innovation happens. Clusters is such an instance where multi-actor innovation processes take place. Given the lack of academic research linking open innovation and clusters literature, Chap. 9 analysis open innovation adoption in clusters based on the Portuguese case.

Finally, we conclude with the current debate on the role of the state around the modern macroeconomic theory. This is a current concern because of the financial crisis that began in the summer of 2007, which changed the thinking of the role of the state in the economy, particularly affecting optimist liberal policies and strengthening the argument for participation of civil society in economic growth. This is evident in guidance from the European Commission under the leadership of President Barroso, who in March 2010 wrote: "[...] the condition for success is a real ownership by European leaders and Institutions. Our new agenda requires a coordinated European response, including with social partners and civil society. If we act together, then we can fight back and come out of the crisis stronger. We have the new tools and the new ambition. Now we need to make it happen. [...] Europe 2020 puts forward three priorities: smart growth (developing an economy based on knowledge and innovation); sustainable growth (promote a more resource efficient, greener and more competitive economy); inclusive growth (fostering a high-employment economy delivering social and territorial cohesion) [...]" (see Barroso 2010). Recent guidance under the leadership of President Juncker, who in June 2016 wrote: "[...] Innovation presupposes an element of novelty and experimentation. The pace of change, particularly in the case of disruptive innovation, may at times be at odds with the dynamics of regulatory processes. While regulation serves many purposes, it needs to be designed in a way that creates the best possible ecosystem for the flourishing of innovation. This will more and more often mean testing, learning and adapting public policies."

The book is structured in the following sections:

Chapter 1 Introduction with overview about (i) the Quadruple Helix Innovation Systems Conceptual Framework; (ii) theories of economic growth and public policies; (iii) some case studies with country examples (table from OECD Science, Technology and Industry outlook OECD).

Chapter 2 A Growth Model for the Quadruple Helix Innovation Systems Conceptual Framework—To describe and explain the model and their results, focusing always on the government's role in our stylized innovation economy.

Chapter 3 Quadruple Helix R&D Growth Models. A Panel Cointegration Analysis Applied to a Sample of OECD Countries to find evidence from a sample of OECD countries for the Quadruple Helix growth model using panel co-integration analysis.

Chapter 4 How Rationales, Actors, and Multi-Level Governance Relate to Innovation Policy Mix develops concepts that instruct policy makers, advisors, and stakeholders on how to design and implement policies.

Chapter 5 The Fourth Helix in Smart Specialization Strategies: The Gap between Discourse and Practice with a particular case study (the Aveiro Region in Portugal) and the process that led to the definition of its Territorial Development Strategy for the 2014–2020 period.

Chapter 6 Supporting Knowledge and Policy-Based Stakeholders in Delivering Regional Impact, develops a technique that channels and instructs regional stakeholders where their innovation focus should be in terms of implementing practices and policies that drive innovation and competitive performance.

Chapter 7 Innovation Evaluation and Measurement: Macro Level and Firm Level Perspectives address relevant considerations about metrics because innovation is recognized as a difficult domain to assess and to measure. Here can be found several macro and micro assessments and innovation measurement exercises.

Chapter 8 Smart Cities and the Quadruple Helix Innovation Systems Conceptual Framework: The Case of Portugal analyses the collaborative dynamics within the smart city arena in Portugal, stressing the role played by the helices of the Quadruple Helix Innovation Systems Conceptual Framework.

Chapter 9 Open Innovation Adoption in Clusters: The Portuguese Case, stretches the notion of "open innovation", usually deployed in innovation management studies, and takes it a phenomenon relevant at the meso sectoral/regional scale. This research draws on a Delphi questionnaire launched to the Portuguese clusters, identifying the main barriers for the development of open innovation activities.

Chapter 10 Conclusion and Future Research.

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CHAPTER 2

Growth Model for the Quadruple Helix Innovation Systems Conceptual Framework

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2.1 Introduction

Innovation has been the main source of growth in countries such as Austria, Finland, Sweden, the United Kingdom and the United States, between 1995 and 2006 (OECD 2010) and, in their urgent quest to find new, prolific and sustainable sources of economic growth, more countries, whether industrialised or emerging, are believed to soon become innovation

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economies. The Europe 2020 Strategy constitutes an example of such a quest in many European countries.

In the industrial era, innovation consisted exclusively of scientific and technological research, performed by academically educated researchers. With time, innovation has outgrown its technology-science-bounded concept. Indeed, fundamental developments have occurred concerning: (i) what innovation is; (ii) who does it; and (iii) how it is done.

According to the *Oslo Manual* (2005), innovation is the introduction of a new product or service, a new process or a new method. Formally specialised researchers no longer hold exclusivity to innovation activities, and incoming innovators are equipped with new, multidisciplinary skills and competences.

In our innovation era, innovation's multidisciplinary nature, and consequent growing complexity and increasing costs, call for a productive structure that facilitates cooperation and information-sharing between profit-seeking agents. Once performed in an environment marked by a culture of "silence is golden", innovation is increasingly arising as a result of co-creation between firms, citizens, universities and government, in an environment characterised by the existence of cooperation networks, embedded in a "we share" culture.

In a linear, top-down, inside-out philosophy, innovation used to be performed within firms that would then sell them to consumers through marketing techniques. Nowadays, firms can no longer count with passive consumers. Worldwide connected, informed and participative, today's citizens are empowered consumers and innovation co-creators. They interact with firms and the government with ideas, suggestions and demands for goods and services with specific characteristics, such as smarter or greener products and services (Arnkil et al. 2010). Such interactions result in firms and governments' engagement in innovation in order to meet concrete demands. Indeed, as acknowledged in Fora (2009), a new balance between technology-driven, competitive-driven and user-driven innovation, with increased weight given to users (consumers) is taking place.

Academia and technological infrastructures establish networks, partnerships and associations to undertake research and development (R&D), and supply technical products and services (e.g., Etzkowitz and Leydesdorff 2000). They are fundamental to the codification of tacit knowledge in the form of goods and services, enabling thus the transfer of knowledge.

All this means that, in a successful innovation economy, big and small, private and public, academic and non-academic institutions, together with well-informed consumers, must share information and co-innovate within networks, symbiotic relationships and collaborations. Interdependence of institutions is the result of the emerging innovation economies (OECD 2009).

A growing innovation economy also requires the public sector to go through significant cultural changes. Governments must innovate and work in interaction with all other economic agents, so as to deliver: solutions to new societal challenges; adequate public services and new policy instruments (Fora 2009). As Powell and Grodal (2005) argue, governments provide the financial support and the regulation system to promote the creation of links between academia and firms, such as science parks, business incubators and other bridge-institutions. Governments can indeed contribute to innovation economies through: infrastructure provision and maintenance; the exercise of intelligent demand; introduction of smart regulation; elimination of obstacles to innovation initiatives; and improvements in the processes for accumulating knowledge and competencies.

The Quadruple Helix Innovation Systems Conceptual Framework captures, we believe, very well the essence of an innovation economy. According to the Quadruple Helix Innovation Systems Conceptual Framework, a nation's economic structure lies on four foundations (four helices)—Citizens, Firms, Academia, Government—its economic growth being generated by continuous innovation activities.

Our goal for the present chapter is to represent mathematically an innovation economy. More precisely, we wish to convey the QH innovation theory through an analytical framework, with which we can demonstrate mathematically the unique and irreplaceable role of each of the four foundations to an innovation economy. The model connects the four helices and investigates analytically their interactions and joint impact on growth.

We set up an innovation-based growth model, with a one-sector structure, complementarities between intermediate goods, and productive public expenditure. The model we use is similar to Afonso et al.'s (2014), which departs from an earlier model of ours, Afonso et al. (2012), in the sense that, here, internal investment costs are not considered, as our main present goal is to show in the simplest form possible, the mechanisms that link the four helices and generate economic growth in an innovation economy.

In assuming a one-sector structure (as Rivera-Batiz and Romer 1991), our Quadruple Helix Innovation Systems Conceptual Framework captures the notion that the whole society is involved in innovation, which occurs as a result of co-creation between the four helices, connected through networks, partnerships and symbiotic relationships.

In this model of ours, firms materialise innovations in the form of goods and services, interacting with and complementing each other, in a cooperative, information-sharing culture (e.g., Carayannis and Campbell 2006, 2009; Arnkil et al. 2010; MacGregor et al. 2010). The concept of complementarities (see, e.g., Matsuyama 1995) seems ideal to portray our innovation era, in which profit-seeking firms benefit from interaction, cooperation and information-sharing. We model complementarities between intermediate firms, as in Thompson (2008).

Citizens take part in the economy by producing, contributing to innovation and by constantly demanding innovative goods and services. Citizens (Civil Society) wish to consume innovative goods and services. Governments undertake productive public expenditure on education, health, infrastructures, technological and innovation services and regulations, which increases the productivity of all economic agents.

This QH growth model is our desired contribution to the growing literature on innovation economies. Additionally, it carries a second contribution to growth literature in the sense that it is an idea-based growth model with public productive expenditure, which, according to Irmen and Kuehnel (2009), is new to literature on public expenditure and economic growth.

Public expenditure currently being under political pressure in many European countries, our main search question and finding is that an increase in the proportion of output spent on productive public expenditures has a positive effect on the economic growth rate in the short (initial level effect), medium (transitional dynamics) and long (steady state) run.

The remainder of the chapter is organised as follows. Section 2.2 describes the model and its main results. Section 2.3 analyses economic policy effects and Sect. 2.4 closes up the chapter with some Final Remarks.

2.2 The QH Innovation Growth Model

In innovation economies, public and private organisations and institutions—governments, universities, research centres, business communities and funding/financing organisations—collaborate with and compete between each other, generating innovation through continuous interactions of multidisciplinary knowledge and information, human resources, financial capital and institutions (Carayannis and Campbell 2006, 2009).

As explained above, we wish to frame analytically, with a growth model, an innovation economy as conceived by the Quadruple Helix Innovation Systems Conceptual Framework. In a QH innovation setting, four economic foundations (helices)—Consumers, Firms, Academia and the Government—cooperate and co-produce, via partnerships, collaborations and symbiotic relationships, technological; social; product; service; commercial; and non-commercial innovations, in a systemic fashion.

Innovation activities and their outcomes are not easy to define or manage. According to the Oslo Manual (OECD 2005), a strict definition of innovation is difficult to attain because of the increasing complexity of innovation processes and the different ways in which they can occur according to types of firms and industries. Generally, academia plays an important role as a source of knowledge and technology, but university-industry relationships can be difficult for firms to manage. New fields of knowledge with fast technological progress, like Nano-Bio-TIC, for example, offer promising commercial opportunities, but pose considerable interaction problems between the different entities involved.

As Yawson (2009) writes, before the 2000s a national system of innovation was conceptually formed by: (i) a set of institutions which jointly or individually contributed to the development and diffusion of new technologies; and (ii) the government which implemented policies aimed at influencing innovation processes. In the 2000s, however, new concepts have emerged, such as innovation systems, global networking in value added and innovation, customers and users, systemic thinking and sustainable innovation.

West and Farr (1989, p. 16), for instance, define innovation as the "... intentional introduction and application within a role, group or organization of ideas, processes, products or procedures, (...) designed to significantly benefit role performance of the group, the organization or the wider society". For Johnson (1992), innovation is a continuous cumulative process involving not only radical and incremental innovation but also the diffusion, absorption and use of innovation. According to the OECD (2009), innovation consists in creating value by developing new solutions to specific problems.

Adopting the broadest definition of innovation, in our stylised inclusive economy, all economic agents participate in the innovation process, meaning that a one-sector structure is set up, as innovation is undertaken with the same production function as that of the final good and intermediate goods and services. Firms materialise innovation in the form of intermediate goods and services, which are inputs in the production function of the economy, the aggregate production function.

Citizens constitute the economy's labour. The economy's aggregate output is produced using: labour, government expenditure, and all the existing intermediate goods and services. The physical units of each intermediate good or service are produced by monopolistic competitive firms. Government is assumed to provide a pure public good—expenditure on education, health, infrastructures, technological and innovation services, and regulations—which increases the productivity of all productive factors. Considered essential for sustained innovation (Lundvall and Borras 1997), there are complementarities in our innovation economy, representing the need for profit-seeking companies to cooperate and share information within networks.

The productive and innovative roles of academia and government are embedded in: (i) the economy's aggregate production function; and (ii) the economy's budget constraint.

The model needs to be understood in a circular perspective: All the existing intermediate goods and services are used to produce the economy's aggregate output. Then, aggregate output can be either consumed or invested. Investment consists of innovation expenditure plus physical capital accumulation. Physical capital and new innovations are needed to produce more intermediate goods and services. These in turn are used in the production of aggregate output.

Let us represent such conceptualised innovation economy through means of a mathematical model.

2.2.1 Production Side—Technology Equation

Government Expenditure

As stated before, the government's role in this stylised innovation economy consists of providing a pure public good—in the form of public expenditure on education, health, infrastructures, technological and innovation services and regulations—which increases the productivity of all factors of production.

Figure 2.1 shows the significant constancy of the public expenditures to GDP ratio, over long periods of time. Therefore, we assume a behavioural version for public expenditures, specifying that in each period of time the flow of public expenditures is a fixed, exogenous proportion of aggregate output.

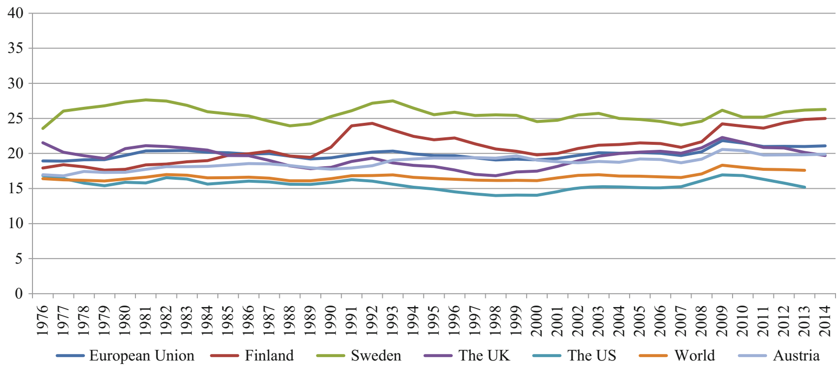

Fig. 2.1 General government final consumption expenditure (% of GDP) (World Bank (available at: http://data.worldbank.org; accessed in October 2015))

We assume that, in every time period t, productive government expenditure $G(t)$ is a constant fraction of output, $Y(t)$. That is:

$$G(t) = \tau Y(t), \qquad 0 < \tau < 1, \tag{2.1}$$

where τ is the exogenous share of aggregate output allocated to public expenditure. Following Barro (1990), productive government expenditure is a flow variable, that is, it does not accumulate over time. The government's budget is balanced in all periods of time. Assuming, for simplicity, zero-public-debt, and zero-consumption-taxes, the government's budget constraint is:

$$G(t) = T(t), \tag{2.2}$$

where $T(t)$ represents lump-sum taxes.

Intermediate Firms

Each intermediate firm is associated with one innovation i and produces its intermediate good or service in exclusivity, reaping forever monopolistic profits. No intermediate firm is pushed out of the market, in this non-destructive creation model.

In each period of time, there are $A(t)$intermediate firms and $A(t)$ innovations, respectively. This number$A(t)$ increases every time, through innovation activities, the source of growth of our modelled economy. Each intermediate firm i ($i = 0 \ldots. A$)contributes to aggregate output production, $Y(t)$, by producing a non-durable good or service, in quantities $x_i(t)$. As in Afonso et al. (2014), there are complementarities between intermediate goods and services in the production function for $Y(t)$, meaning that an increase in the demand for one intermediate good or service implies an increase in the demand for the other intermediate goods and services.

Aggregate Output—Final Good

The economy's aggregate output is regarded as the unique economy's final good, $Y(t)$, which is produced using as productive factors: (i) labour, $L(t)$ equal to the economy's total population, and here assumed constant; (ii) public expenditure, $G(t)$, an assumed constant proportion of the economy's output; and (iii) a number $A(t)$ of non-durable differentiated intermediate goods and services i ($i = 0 \ldots. A$), each one of them produced in quantities $x_i(t)$. The economy's aggregate production function for $Y(t)$ is:

$$Y(t) = L(t)^{1-\alpha-\beta} G(t)^{\beta} (x_0(t)^{\gamma} + x_1(t)^{\gamma} + x_2(t)^{\gamma} + \ldots. + x_A(t)^{\gamma})^{\varphi},$$

equivalent to:

$$Y(t) = L(t)^{1-\alpha-\beta} G(t)^{\beta} \left(\int_0^{A(t)} x_i(t)^{\gamma} di \right)^{\varphi},$$

which, substituting $G(t)$ by its equivalent given in Eq. (2.1), becomes:

$$Y(t) = L(t)^{1-\alpha-\beta} (\tau Y(t))^{\beta} \left(\int_0^{A(t)} x_i(t)^{\gamma} di \right)^{\varphi},$$

That is:

$$Y(t) = \tau^{\frac{\beta}{1-\beta}} L(t)^{\frac{1-\alpha-\beta}{1-\beta}} \left(\int_0^{A(t)} x_i(t)^{\gamma} di \right)^{\frac{\varphi}{1-\beta}}, \qquad \gamma\varphi = \alpha, \qquad \frac{\varphi}{1-\beta} > 1. \quad (2.3)$$

We must impose the parameter restriction that $\gamma\varphi = \alpha$ so as to preserve homogeneity of degree one, that is, so that our aggregate production function is a constant return to scale production function.

Assumption $\frac{\varphi}{1-\beta} > 1$ is made so that the intermediate goods and services x_i are complementary to one another; that is, so that an increase in the demand for one intermediate good or service increases the demand for the other inputs, as can be verified in the expression for the marginal productivity of x_j below:

$$\frac{\partial Y(t)}{\partial x_j(t)} = \frac{\alpha}{1-\beta}\tau^{\frac{\beta}{1-\beta}}L(t)^{\frac{1-\alpha-\beta}{1-\beta}}x_j(t)^{\gamma-1}\left(\int_0^{A(t)} x_i(t)^{\gamma}di\right)^{\frac{\varphi}{1-\beta}-1}.$$

Assuming that it takes one unit of physical capital $K(t)$ to produce one physical unit of any intermediate good or service, $K(t)$ is related to inputs $x_i(t)$ by the rule:

$$K(t) = x_0(t) + x_1(t) + \ldots + x_A(t),$$

That is:

$$K(t) = \int_0^{A(t)} x_i(t)di. \tag{2.4}$$

In each period of time, the economy's total stock of physical capital consists of all the existing intermediate goods and services.

Innovation

As stated earlier, we wish to frame the argument that all economic agents participate in the innovation process of an innovation economy. We hence specify a one-sector productive structure, according to which innovation is undertaken by the whole population, with the same production function as that of the final good $\Upsilon(t)$ and of the intermediate goods and services. We derive our one-sector structure from Rivera-Batiz and Romer (1991).

We further assume that innovation i requires P_A i^{ξ} units of foregone output, where P_A is the fixed, exogenous cost of one new innovation in units of foregone output, and i^{ξ} represents an additional cost of innovation i in terms of foregone output, meaning that the higher the index ($i = 0$ .... A) of one innovation, the higher its innovation cost. Conveying the notion that the more innovations there are, the more difficult, thus costly, it is to make a new innovation. Like in Evans et al. (1998), this extra cost allows us to obtain analytically a balanced growth path (BGP) solution, that is a solution with a constant economic growth rate, which is one of Kaldor's (1957) stylised facts about growth.

Summing up, in each period of time, there are $\dot{A}(t) = A(t+1) - A(t)$ new innovations, hence total innovation expenditure mounts to $P_A(t)\dot{A}A(t)^{\xi}$.

Total Investment

With zero depreciation for simplicity, total investment in each period, $I(t) = W(t+1) - W(t) = \frac{dW(t)}{dt} = \dot{W}(t)$, is equal to investment in physical capital, $\dot{K}(t) = \frac{dK(t)}{dt}$, plus investment in innovation, $P_A(t)\,\dot{A}(t)\,A(t)^{\xi}$. That is:

$$\dot{W}(t) = \dot{K}(t) + P_A(t)\,\dot{A}(t)\,A(t)^{\xi}. \tag{2.5}$$

From Eq. (2.5), one can derive (backwards) total capital, $W(t)$, equal to physical capital, $K(t)$ plus innovation capital, $P_A\frac{A(t)^{\xi+1}}{\xi+1}$. That is:

$$W(t) = K(t) + P_A\frac{A(t)^{\xi+1}}{\xi+1}. \tag{2.6}$$

Closing up the model, the closed economy's budget constraint is:

$$Y(t) = C(t) + G(t) + I(t),$$

equivalent to:

$$\dot{W}(t) = Y(t) - G(t) - C(t). \tag{2.7}$$

Technology Equation

Let us now solve the production side of the economy for its BGP solution and thus obtain the Technology Equation. The Technology Equation is the equation that unites the pairs of constant growth rates and interest rates (g, r) for which the production side of the economy is in a BGP equilibrium.

In a perfect competition environment, final-good producers are price takers in the market for inputs. In equilibrium they equate the price of each input with its marginal productivity. The price of $Y(t)$is normalised to one. The demand curve faced by each intermediate firm is, then:

$$\frac{\partial Y(t)}{\partial x_j(t)} = R_j(t) = \frac{\alpha}{1-\beta}\tau^{\frac{\beta}{1-\beta}}L(t)^{\frac{1-\alpha-\beta}{1-\beta}}x_j(t)^{\gamma-1}\left(\int_0^{A(t)} x_i(t)^{\gamma}di\right)^{\frac{\varphi}{1-\beta}-1}, \tag{2.8}$$

where $R_j(t)$ is the price of intermediate good or service j.

Turning to intermediate firms' production decisions, they operate in a monopolistic competition market. Once decided to enter this market, each intermediate firm wants to maximise its profits in each period of time. The physical production of each unit of any intermediate good or service requires one unit of physical capital, $K(t)$, whose cost is the real interest rate, r. Hence, in each period, an intermediate firm (say intermediate firm j) maximises profits,$\pi_j(t)$, taking as given the demand curve for its good:

$$\max_{x_j(t)} \pi_j(t) = R_j(t)x_j(t) - rx_j(t),$$

which leads to the usual markup rule:

$$R_j = \frac{r}{\gamma}. \tag{2.9}$$

Markup rule (2.9) means that each intermediate firm charges, for its intermediate good or service, a price $R_j(t)$ which is higher than the real interest rate, that is, higher than physical capital's marginal cost.

The decision to enter the market and become an intermediate firm depends on an intertemporal cost-benefit analysis: At each time t, in order to enter the market and produce the *Ath* input, an intermediate firm must spend up-front an innovation cost given by $P_A A(t)^{\xi}$, where, as mentioned earlier, P_A is the fixed cost, in units of foregone output, and i^{ξ} is the additional cost of patent i in terms of foregone output. Entering the market, each intermediate firm is the monopolistic producer of a differentiated good or service i, earning profits in every period of time $\pi_i(t)$ up to infinity. In each period of time, there are agents equating whether to become an intermediate firm. Each intermediate firm's decision to enter the market requires comparison between the innovation cost, paid up-front $P_A A(t)^{\xi}$, and the discounted value of the stream of profits obtained from t to infinity $\int_t^{\infty} e^{-r(v-t)}\pi_i(v)dv$. The dynamic intermediate firm's zero-profit condition (immediate—at time t—innovation cost equals the present value of monopolistic profits) is:

$$P_A A(t)^{\xi} = \int_t^{\infty} e^{-r(v-t)} \pi_i(v) dv,$$

which, time-differentiating, assuming no bubbles, is equivalent to:

$$\xi g_A = r - \frac{\pi_i}{P_A A^{\xi}}, \tag{2.10}$$

where $g_A = \frac{\frac{dA(t)}{d(t)}}{A(t)} = \frac{\dot{A}(t)}{A(t)}$ is the rate of growth of new innovations, the growth engine of this economy.

All intermediate firms face the same market conditions. Such symmetry of the model implies that all intermediate firms charge an equal price for their respective good or service, that is $R_j(t) = R(t)$; and produce their good or service in the same quantities, that is, $x_j(t) = x(t)$; consequently earning equal profits, that is $\pi_j(t) = \pi(t)$. Hence the model simplifies considerably, as:

(i) the price for each of all intermediate good and service $R(t)$ can be rewritten (dropping time notations henceforth) as:

$$R = \Omega_R A^{\frac{\varphi-1+\beta}{1-\beta}} x^{\frac{\alpha-1+\beta}{1-\beta}}, \tag{2.11}$$

where $\Omega_R = \frac{\alpha}{1-\beta} \tau^{\frac{\beta}{1-\beta}} L^{\frac{1-\alpha-\beta}{1-\beta}}$ is a constant value;

(ii) intermediate firms' profits:

$\pi(t) = R(t)x(t) - rx(t) = (1-\gamma)R(t)x(t)$, are rewritten as:

$$\pi = (1-\gamma)\Omega_R A^{\frac{\varphi-1+\beta}{1-\beta}} x^{\frac{\alpha}{1-\beta}}; \tag{2.12}$$

(iii) and quantities $x(t)$ are now given by:

$$x = A^{\xi} \left(\frac{\Omega_R}{R} \right)^{\frac{1-\beta}{(1-\beta)-\alpha}}, \tag{2.13}$$

where, in order to obtain a BGP solution, we impose the following parameter relationship:

$$\xi = \frac{\phi - (1 - \beta)}{(1 - \beta) - \alpha}.$$

As we will explain later on, in a BGP equilibrium, the interest rate is constant and hence, recalling markup rule (2.9), so is $R = \frac{r}{\gamma}$. Now, according to expression (2.11), for R to be constant, the following equality must hold:

$$\left(\frac{\varphi - 1 + \beta}{1 - \beta} \right) g_A = - \left(\frac{\alpha - 1 + \beta}{1 - \beta} \right) g_x,$$

which is equivalent to:

$$g_x = \xi g_A.$$

Because $x_j(t) = x(t)$, for all j, Eq. (2.4) also simplifies to:

$$K = Ax,$$

meaning that physical capital K grows at the rate:

$$g_K = g_A + g_x = (1 + \xi) g_A.$$

Likewise, production function (2.3) is rewritten as:

$$Y = \tau^{\frac{\beta}{1-\beta}} L^{\frac{1-\alpha-\beta}{1-\beta}} A^{\frac{\varphi}{1-\beta}} x^{\frac{\alpha}{1-\beta}}. \tag{2.14}$$

Log-time-differentiation of production function (2.14) gives us the growth rate of output. Indeed, Eq. (2.14) is equivalent to:

$$\ln Y = \ln \tau^{\frac{\beta}{1-\beta}} + \ln L^{\frac{1-\alpha-\beta}{1-\beta}} + \ln A^{\frac{\varphi}{1-\beta}} + \ln x^{\frac{\alpha}{1-\beta}},$$

which is equivalent to:

$$\frac{d\ln Y}{dt} = \left(\frac{\beta}{1-\beta}\right)\frac{d\tau}{dt} + \left(\frac{1-\alpha-\beta}{1-\beta}\right)\frac{dL}{dt} + \left(\frac{\varphi}{1-\beta}\right)\frac{dA}{dt} + \left(\frac{\alpha}{1-\beta}\right)\frac{dx}{dt},$$

which is equivalent to:

$$g_Y = \left(\frac{\beta}{1-\beta}\right)g_\tau + \left(\frac{1-\alpha-\beta}{1-\beta}\right)g_L + \left(\frac{\varphi}{1-\beta}\right)g_A + \left(\frac{\alpha}{1-\beta}\right)g_x,$$

Which, as τ and L are constant, is equivalent to:

$$g_Y = \left(\frac{\varphi}{1-\beta}\right)g_A + \left(\frac{\alpha}{1-\beta}\right)g_x,$$

finally equivalent to:
$g_Y = \left(\frac{\varphi+\alpha\xi}{1-\beta}\right)g_A = (1+\xi)g_A$.We have then verified that:

$$g_Y = g_K = (1+\xi)g_A.$$

It follows that Eq. (2.10) can be presented as:

$$g_Y = \frac{1+\xi}{\xi}\left(r - \frac{\Omega_Y}{R^{\frac{\alpha}{(1-\beta)-\alpha}}}\right), \qquad \Omega_Y = \frac{(1-\gamma)}{P_A}\Omega_R^{\frac{1-\beta}{(1-\beta)-\alpha}} \tag{2.15}$$

Equation (2.15), is our Technology Equation. It unites all the BGP pairs (g, r) that constitute equilibria on the production side of this economy.

2.2.2 Consumption Side—the Euler Equation

The inhabitants of this economy produce, innovate and consume. They are the fourth foundation of the Quadruple Helix Innovation Systems Conceptual Framework. Informed and cultivated, our innovation economy's citizens are consumers who desire innovative products and services.

Innovative products and services are all aggregated in the form of the economy's unique final good, Υ. This means that we can use the standard intertemporal consumption specification for capturing consumers' decisions. Infinitely lived, homogeneous, they wish to maximise, subject to a budget constraint, the discounted value of their representative utility:

$$\max_{C(t)} \int_0^{\infty} e^{-\rho t} \frac{C(t)^{1-\sigma}}{1-\sigma} dt \tag{2.16}$$

$$s.t. \qquad \dot{E}(t) = rE(t) + w(t) - C(t) - T(t), \tag{2.17}$$

where variable $C(t)$ is consumption of $\Upsilon(t)$ in period t,$U[C(t)] = \frac{C(t)^{1-\sigma}}{1-\sigma}$ is the consumers' utility function, $\rho>0$ is the rate of time preference and $\sigma^{-1} > 0$ is the elasticity of substitution between consumption at two periods in time. In this closed economy, individuals' budget constraint is Eq. (2.17). Variable $E(t)$ stands for total assets, r is the real interest rate, $w(t)$ is the real wage rate, and it is assumed that households provide one unit of labour per unit of time. Lump-sum taxes are given by $T(t)$.

The current-value Hamiltonian is:

$H(t) = \frac{C(t)^{1-\sigma}}{1-\sigma} + \mu(t)[rE(t) + w(t) - C(t) - T(t)]$.

The transversality condition is $\lim_{t\to\infty} \mu(t)E(t) = 0$, where $\mu(t)$ is the shadow price of assets. The first-order condition is:

$$\frac{dH}{dC} = 0,$$

equivalent to:

$$C^{-\sigma} = \mu,$$

which, log-time-differentiating, gives:

$$-\sigma g_C = g_\mu \tag{2.18}$$

The co-state condition is:

$$\frac{dH}{dE} = \rho\mu - \dot{\mu}\,,$$

equivalent to:

$$\mu r = \rho\mu - \dot{\mu}\,,$$

equivalent to:

$$g_\mu = \rho - r. \tag{2.19}$$

Equations (2.18) and (2.19) combined together give us the familiar Euler Equation that describes consumers' decisions, in terms of pairs (g, r), along their BGP equilibrium:

$$g_c = \frac{\frac{dC(t)}{dt}}{C(t)} = \frac{\dot{C}}{C} = \frac{1}{\sigma}(r - \rho). \tag{2.20}$$

The Euler Eq. (2.20) says that the interest rate, r, is constant in a BGP equilibrium.

2.3 General Equilibrium

We can now solve the general equilibrium BGP solution, that is, the equilibrium in which both production and consumption sides are simultaneously in equilibrium. Because, in deciding their consumption paths, citizens are also deciding their savings paths. Savings finance investment, which is required for aggregate output growth. The general equilibrium occurs when savings exactly meet investment needs.

Time-differentiation of investment Eq. (2.6) tells us that total capital W grows at the same rate as Y. Let us see why:

$$\frac{\dot{W}}{W} = \frac{\dot{K}}{K}\frac{K}{W} + \frac{\dot{A}}{A}\frac{A^{1+\xi}}{W}P_A = (1+\xi)g_A\frac{K}{W} + g_A\frac{A^{1+\xi}}{W}P_A = (1+\xi)g_A\frac{K + \frac{P_A A^{1+\xi}}{1+\xi}}{W},$$

That is:

$$g_W = (1 + \xi) g_A.$$

Then the economy's budget constraint (2.7) says that, because $G = \tau Y$, and W grows at the same rate as Y, a constant g_W requires that consumption C also grows at the same rate as W and Y:

$$\frac{\dot{W}}{W} = \frac{(1-\tau)Y}{W} - \frac{C}{W} \Rightarrow \dot{g}_W = 0 \Leftrightarrow \left[\frac{(1-\tau)Y}{W}\right]^{\bullet} = \left[\frac{C}{W}\right]^{\bullet} \Leftrightarrow g_C = g_W = g_Y.$$

Now we know that consumption and aggregate output grow at the same rate. With labour constant, the per-capita economic growth rate is equal to the aggregate output growth rate, and it is such that:

$$g_C = g_Y = g_K = g_W = (1 + \xi) g_A = g.$$

2.3.1 *The Steady-State Equilibrium*

The BGP general equilibrium solution is obtained by solving the system of two Eqs. (2.15) and (2.20), in two unknowns, the interest rate r and the growth rate g:

$$\begin{cases} g = \dfrac{1}{\sigma}(r - \rho) \\ g = \dfrac{1+\xi}{\xi}\left[r - \dfrac{\Omega}{r^{\frac{\alpha}{(1-\beta)-\alpha}}}\right] \end{cases}, \qquad r > g > 0, \tag{2.21}$$

where $\Omega = \Omega_Y \gamma^{\frac{\alpha}{(1-\beta)-\alpha}}$. Restriction $r > g > 0$ is imposed so that: (i) present values will be finite; and (ii) our solution(s) to system (2.21) have positive interest and growth rates.

Proposition Existence of a unique steady-state solution for $\sigma > 1$ and $\Omega^{\frac{1-\alpha-\beta}{1-\beta}} < \rho$.

Proof As depicted in Fig. 2.2, in the space (g, r), the linear Euler Eq. (2.20) has inclination $\frac{\partial g}{\partial r} = \frac{1}{\sigma} > 0$, the value it assumes on the vertical axis is $g = -\frac{\rho}{\sigma}$.; and the value it takes on the horizontal axis is $r = \rho$. To ensure that $r > g$, we

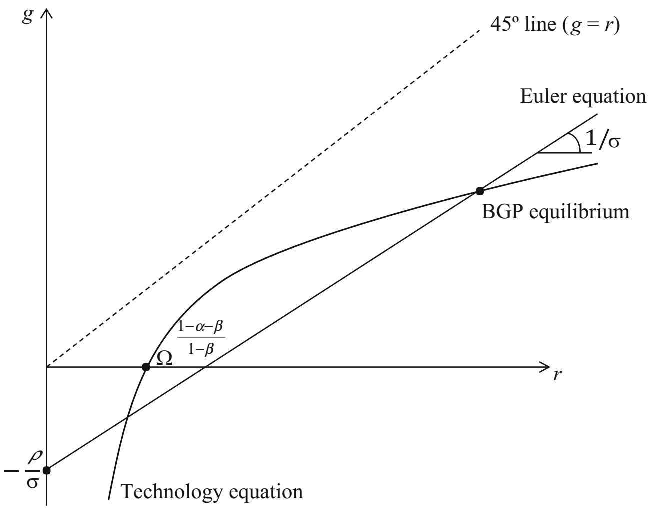

Fig. 2.2 Analytical BGP general equilibrium solution

impose $\sigma > 1$ so that the Euler Eq. (2.20) lies below the 45° line (e.g., Rivera-Batiz and Romer 1991). The Technology Eq. (2.15) is positively sloped and decreasing:

$$\frac{\partial g}{\partial r} = \frac{(1+\xi)}{\xi} + \frac{(1+\xi)}{\xi}\frac{\alpha}{1-\beta-\alpha} r^{\frac{\beta-1}{(1-\beta)-\alpha}}\ \Omega > 0,$$
$$\frac{\partial^2 g}{\partial r^2} = \frac{(\beta-1)}{1-\beta-\alpha}\frac{(1+\xi)}{\xi}\frac{\alpha}{1-\beta-\alpha} r^{\frac{\alpha}{(1-\beta)-\alpha}}\Omega \ < 0.$$

When $r \to 0$, $g \to -\infty$, and the value it takes on the horizontal axis is $r = \Omega^{\frac{1-\alpha-\beta}{1-\beta}}$.

Given the positive and decreasing slope of the Technology Equation, provided that $\Omega^{\frac{1-\alpha-\beta}{1-\beta}} < \rho$, there is one equilibrium (BGP equilibrium) and it is unique, for the two curves cross each other just once in the first quadrant of the (g, r) space.

In order to better illustrate the unique general BGP equilibrium, and given the non-linearity of the Technology Equation, let us solve the system through a numerical exercise. The baseline chosen parameter values are:

$$\sigma = 2; \quad \rho = 0.002; \quad \alpha = 0.4; \quad \beta = 0.3; \quad \gamma = 0.1;$$
$$\varphi = 4; \quad \xi = 11; \quad L = 1; \quad P_A = 15, \quad \tau = 0.15,$$

where the values for α, γ and consequently $\varphi = \frac{\alpha}{\gamma}$ are the same as those used by Evans et al. (1998) in their numerical solution. The value for parameter ξ is $\xi = \frac{\varphi - (1-\beta)}{(1-\beta)-\alpha} = 11$. The value for the preference parameter σ is in agreement with those found in empirical studies such as Barro and Sala-i-Martin (2004), whereas we have chosen a small ρ in order to allow for small equilibrium interest rate values. Population is normalised to unity, as often done with growth models. The value for parameter τ is in agreement with Irmen and Kuehnel (2009). And the value for P_A is chosen so as to give us realistic values for the equilibrium growth rate and interest rate. With the chosen values, system (2.21) becomes:

$$\begin{cases} g = 0.5r - 0.001 \\ g = 1.091\left[r - \dfrac{0.000113}{(r)^{1.333}}\right] \end{cases} \qquad r > g > 0,$$

Figure 2.3, with r on the horizontal axis and g on the vertical axis, helps us visualise this economy's BGP general equilibrium numerical solution, which is:

$$r = 0,07; \qquad g = 0,034$$

2.3.2 Transitional Dynamics

In order to observe the economy converging towards its steady state, we proceed with transitional dynamics analysis, using numerical integration. Let us start by considering variables: (i) marginal productivity of total capital, $\chi_1 \equiv \Upsilon / W$; and (ii) consumption-total capital ratio, $\chi_2 \equiv C/W$, which are constant in steady state; that is,

$$\frac{\dot{\chi}_1}{\chi_1} = \frac{\dot{Y}}{Y} - \frac{\dot{W}}{W} \text{ and } \frac{\dot{\chi}_2}{\chi_2} = \frac{\dot{C}}{C} - \frac{\dot{W}}{W} \tag{2.22}$$

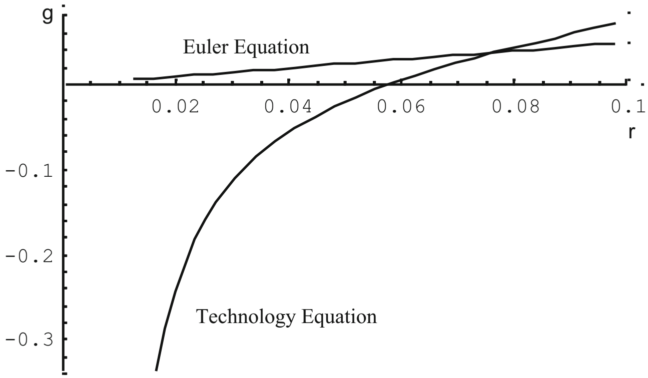

Fig. 2.3 Numerical BGP general equilibrium solution

The system of autonomous differential equations in variables χ_1 and χ_2 is obtained from (2.2), (2.7), (2.15), (2.20) and (2.22). The explicit analytical functional expressions of the differential equations are complex and quite tedious. Hence, in a reader-friendly form, we present the system obtained for the baseline parameter values given in the previous section:

$$\begin{cases} \frac{\dot{\chi}_1}{\chi_1} = 11,9585\chi_1 - 59,7096\chi_2 + 0,2797 \\ \qquad - \frac{0,0025}{(78,3020\chi_1 - 358,7810\chi_2 + 1,7090)^{1,3(3)}} \\ \frac{\dot{\chi}_2}{\chi_2} = 5,0227\chi_1 - 25,9086\chi_2 + 0,1182 \end{cases} \tag{2.23}$$

System (2.23) is solved through the fourth-order Runge–Kutta classical numerical method,[1] and considering the required initial values $\chi_1(1)=0.091$ and $\chi_2(1)=0.040$ (see Table 2.1 with the initial and steady-state values).[2]

Figure 2.4 depicts the decreasing paths of both χ_1 and χ_2 from their respective initial values towards steady-state values. Taking into account the

Table 2.1 Initial and steady-state values for relevant variables

	With τ = 0.15		*With τ = 0.20*	
	t = *1*	t = t*	t = *1*	t = t*
$\chi_1 = Y/W$	0.0907	0.0504	0.0995	0.0576
$\chi_2 = C/W$	0.0400	0.0152	0.0402	0.0158
Interest rate, r	0.000443	0.070314	0.00719	0.079634
Growth rate, g	–0.00078	0.034157	0.002595	0.038817

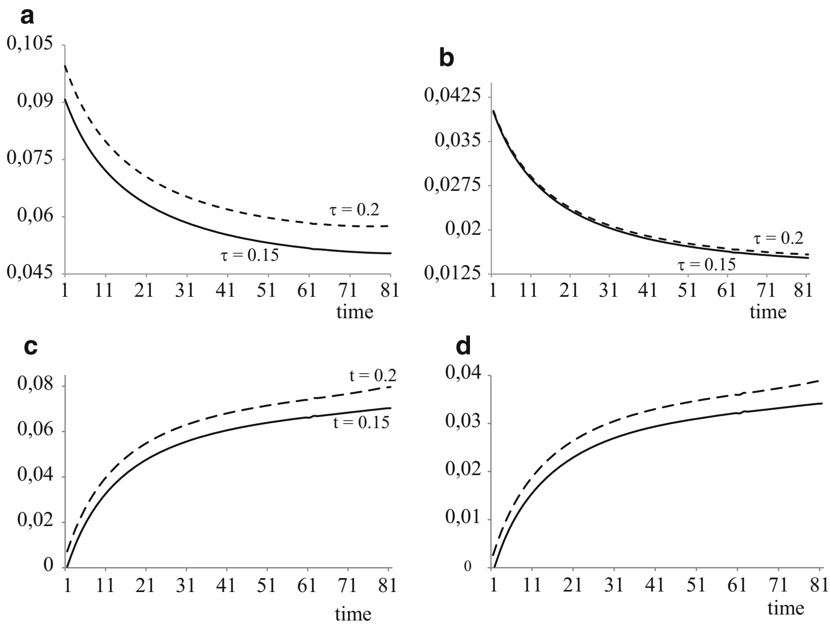

Fig. 2.4 *Transitional dynamics* (**a**) for χ_1, (**b**) for χ_2, (**c**) for the interest rate, (**d**) for economic growth rate

paths of χ_1 (Fig. 2.4a) and χ_2 (Fig. 2.4b), we can easily obtain the paths of the interest rate (Fig. 2.4c) and of the economic growth rate (Fig. 2.4d).

2.3.3 Economic Policy Effects

In many countries, current times are of downward pressure on public expenditures. It is our belief that, as one of the foundations of an innovation economy, the government's role cannot be underestimated nor dismissed. The OECD (2010), too, argues that the long run growth of innovation economies relies crucially on continued baseline public investment in education, infrastructure (supply and maintenance) and research.

Regarding literature on the impact of public expenditures on economic growth, Aschauer's (1989) seminal paper and its followers find large effects of public capital on growth and productivity. Sturm et al. (1998), however, argue that this first generation of studies present substantial methodological and econometric limitations. Holz-Eakin and Lovely (1996, p.106), for instance, observe the inexistence of formal economic models predicting the effects of infrastructure on productivity. Still, according to Romp and De Haan's (2007) survey, more recent studies tend to converge in finding moderate positive effects of public expenditures on per-capita income and on economic growth.

Wishing to highlight theoretically the government's role in our stylised innovation economy, we analyse the effects on growth of an increase in the share of productive public expenditures on output. We analyse the effects of an increase from 15 to 20 % in the share of output allocated to public expenditure, τ. Table 2.1 summarises the short- and the long-run effects of this economic policy. Figure 2.3 shows the transitional dynamics from $t = 1$ towards the steady-state period, $t = t^*$.

An increase in τ induces an upwards jump (short-run effect) in both χ_1 (from 0.0907 to 0.0995), and χ_2 (from 0.0400 to 0.0402). Then, both ratios decrease at decreasing rates (medium-run effect) towards their steady-state new values (long-run effect), which are higher than initially.

The increase in the public expenditure share τ increases both the interest rate and the economic growth rate. Indeed, a higherχ_1, induced by this policy, reflects a higher marginal productivity of total capital, thus generating a higher economic growth rate.

Looking into related literature, for instance Segerstrom (2000), with a model in which innovation results from classic scientific and technological R&D activities, finds that a direct subsidy to R&D increases the economic growth rate. As already highlighted, in our model, innovation encompasses more than scientific and technological R&D activities. It consists in the development of a new product, service, process or method, and is performed by all economic agents. In this context, we have shown that an increase in public expenditure on education; health; infrastructural provision and maintenance; technological and innovation services; and regulations—which increases the productivity of all inputs—is an effective alternative economic policy to achieve higher economic growth.

2.4 Final Remarks

A growing number of developed and emerging economies are assuming the character of innovation economies, meaning that innovation is their main source of economic growth.

According to the Quadruple Helix Innovation Systems Conceptual Framework, four foundations—Firms, Academia, Government and Consumers—sustain an innovation economy. We have portrayed such an economy with a growth model that reinterprets a R&D-based growth model as an innovation-based growth model. In our model, innovation—the engine of growth—is performed by all citizens, in a one-sector productive structure specification. Government contributes to this economy through the provision of productive public expenditure that increases all inputs' productivity. We have also assumed complementarities between intermediate inputs in the aggregate production function, as it conveys the notion of the benefits from cooperation and information-sharing between profit-seeking firms.

With the introduced model, we have analysed questions concerning the importance to economic growth of complementarities between profit-seeking firms, productive public expenditure and policies to achieve higher economic growth.

Innovation's nature has extended beyond technological and scientific R&D activities. *The Oslo Manual* defines innovation as the introduction of a new product or service, a new process or a new method. Such innovation is increasingly multidisciplinary, extremely competitive and costly, compelling innovative agents to cooperate and share within networks, symbiotic relationships and collaborations. As Carayannis and Campbell (2009) write, innovation systems generate a democracy of knowledge, whose creation is transdisciplinary, non-linear, hybrid and shared. Yawson (2009), for example, writes that advances in biotechnology, information telecommunication technologies (ICT) and nanotechnology have stimulated innovation and convergence, but at the same time, have revealed the importance of adequate regulations, and have introduced a need for society awareness.

This new, multidisciplinary, innovation carries the implication that no single innovative agent has the resources or the competences to act alone. Interdependence of institutions is indeed the distinguishing feature of innovation economies. Specifying the beneficial cooperation and sharing interactions between intermediate firms through the presence of complementarities between all the intermediate productive units, the introduced model conveys analytically the result that an increase in complementarities in the innovation economy does increase economic growth.

Yawson (2009) argues that the Quadruple Helix Innovation Systems Conceptual Framework can give orientation to policy makers. Recognising that innovation by creative citizens determines the success of a country's innovation strategy, innovation systems start with a national innovation goal, which should be expressed by the government. In the model presented here, the government's role is specified analytically as it being the provider of a pure public good, in the form of productive expenditure on education, health, infrastructure, technological and innovation services and regulations, which increases the productivity of all inputs.

Our main goal has been to highlight analytically the government's role as one of the foundations to an innovation economy. In our model, productive public expenditures have an important economic role, and we have identified one economic policy with positive effects on growth. An increase in government productive expenditures increases economic growth, not only in the short run, but also in the long run.

Notes

1. Since this classical method solves the differential equation with suitable precision, we need not consider more sophisticated methods.
2. We also checked the robustness of the results of the transitional dynamics to shocks. The results were obtained from numerical simulations in which one parameter or an initial condition at a certain time is allowed to deviate from its baseline value. The general conclusion is that the model's qualitative behaviour is similar for the ranges of parameter values tested. In fact, similar stable saddle paths to steady state were obtained, differing only slightly in the specific levels of the steady state of the variables which they approach.

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CHAPTER 3

Quadruple Helix R&D Growth Models: A Panel Cointegration Analysis Applied to a Sample of OECD Countries

Sara Paulina De Oliveira Monteiro and Maria Adelaide Pedrosa da Silva Duarte

3.1 Introduction

The reality of the so-called innovation economies led to a new research agenda on innovation—the National Systems of Innovation (NSI), that emerged during the late 1980s and 1990s (Freeman 1987, 1999; Lundvall 1988, 1992; Leydesdorff and Meyer (2006), Nelson and Winter (1982, Nelson and Rosenberg (1993), Nelson and Romer (1996) and Pelikan 1988). More recently the NSI research gave rise to the Quadruple Helix

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(QH) Innovation Systems Conceptual Framework Liljemark (2001), (Carayannis and Campbell 2006, 2009a, b; Arnkil et al. 2010; MacGregor et al. 2010), seeking to explain the new reality about innovation faced by those economies and its interplay with economic growth. Following this approach, the economic structure of a country relies on four helices: on one hand the university and technology infrastructures, on the other hand on firms, government and the civil society where differentiated productive units that are complementary and interact with each other are responsible for growth by generating a permanent stream of innovations.

The growing importance of this body of literature where evolutionary and institutional economics play a central and indisputable role is nowadays fully recognized by international organizations such as the Organisation for Economic Co-operation and Development (OECD) that produce policy recommendations about innovation (see OECD 2014) grounded on the aforementioned literature.

QH, though a very rich concept about the characterization of the innovation process—the functioning of the four helices in a framework marked by partnerships, collaborative networks and symbiotic relationships—was not subject to modelling attempts in a theoretical framework, limiting therefore the possibility to test it. Quite recently, Afonso et al. (2012), Monteiro (2013) and Afonso et al. (2014) contributed to fill the gap by modelling the QH concept on the basis of (two) research and development (R&D) growth models. Additionally, Monteiro (2013) presents the first attempt to empirically test the main predictions of the first QH-R&D growth model by Afonso, Monteiro and Thompson (see Afonso et al. 2012) with the help of non-stationary panel techniques. The author proved that for a sample of 24 OECD countries, during the period 1980–2008, distinct but complementary productive units or productive expenditures by the government are conductive to higher growth.

Our empirical analysis relies heavily upon Monteiro (2013), but we extent the scope of the author's analysis by regressing long-run equilibrium equations (LR) that allow for heterogeneity of the coefficients of the RHS variables; a methodological strategy meant to accommodate data heterogeneity between countries, a characteristic that is observed in the sample. Additionally, we tested short-run equilibrium regressions to account for transitional dynamics with special emphasis for the role played by institutional or context variables. As for Monteiro (2013), our results confirm the main model predictions.

The reminder of the chapter is organized into five sections as follows: the next section highlights the main predictions by the R&D growth model to be tested and surveys the first empirical study aimed at that purpose; section three describes data; section four deals with the empirical model by focusing on the growth regressions used, econometric strategy implemented and on the results; and finally in section five concluding remarks are outlined.

3.2 Innovation QH-R&D Growth Models: Theoretical Predictions and Evidence

Let us briefly recall the main characteristics of the theoretical model that we are going to test. This is a one-sector R&D growth model with public productive expenditures, designed to represent the QH innovation concept by emphasizing the role that the four helices—Academia & Technological Infrastructures, Firms, Government and Civil Society—play in the innovation process and consequently on economic growth.

Academia & Technological Infrastructures and Firms are specialized intermediate productive units (IPUs) that give birth to innovations materialized under the form of new varieties of intermediate goods, in a framework characterized by a cooperative and knowledge-sharing culture. It is worth mentioning the crucial roles played by Technological Infrastructures in the innovation process. These are R&D infrastructures that are responsible not only for the creation of networks intended for R&D activities and for the supply of technical goods and services but also for codifying tacit knowledge and allowing in this way the transfer of technology through networks. Government's funding and regulation system provides links between Academia and Firms through the creation of bridge-institutions like science parks, technology business incubators, among others. Finally, Civil Society contributes to the economy both at the supply and demand sides: by its labour services in the production of the final good as well as in the innovation process and by demanding more innovative goods over time. Two crucial assumptions are made in order to take into account the abovementioned nature of the QH in the innovation process. The inputs of the IPUs are complementary for the production of the final good $\Upsilon(t)$, as in Thompson (2008), based on Evans et al. (1998) and public productive expenditures are included, as in Afonso et al. (2012) and Monteiro (2013) building on Barro (1990).

This is a one-sector R&D growth model that produces the final good $Y(t)$, using a constant amount of labour, $L(t)$, public expenditures, $G(t)$, and intermediate inputs, $x_i(t)$. These in turn are produced by a number of IPUs equal to $A(t)$ at time t, with $i = 0, \ldots, A$, where i denotes the index for a new variety of intermediate goods (i.e. innovation i) and each IPU only produces a variety of intermediate goods. The total amount of all the varieties of intermediate inputs used in the production of final output is given by

$$\int_0^{A(t)} x_i di,$$

and the IPUs inputs x_i are complementary, that is, the increase in the quantity of one input leads to the increase of the marginal productivity of other inputs. Additionally, government provides a public good through expenditures on education, health, infrastructures, technological services and innovation as well as on the regulation system that increases the productivity of all the factors of production. At time (t), productive public expenditures, $G(t)$, are a constant share of the output $Y(t)$:

$$G(t) = \tau Y(t) \text{ with } 0 < \tau < 1 \tag{3.1}$$

And according to the assumptions mentioned above, the specification of the final good, $Y(t)$, production function is the following:

$$Y(t) = L(t)^{1-\alpha-\gamma} G(t)^{\beta} \left(\int_0^{A(t)} x_i \mathrm{di} \right)^{\phi} \quad \text{with } \; 0 < \tau < 1 \tag{3.2}$$

Furthermore, the authors prove that the model has a unique balanced growth path solution for plausible values of the parameters and two theoretical predictions, Afonso et al. (2012) and Monteiro (2013): (a) an increase in the rate of public investment leads to an increase in the equilibrium growth rate and (b) an increase in the complementarities between the IPUs inputs leads to an increase in the equilibrium growth rate.

Monteiro (2013) tested the above-mentioned predictions based on a specification of the production function (2) for a sample of OECD countries over the period 1980–2008 making use of CANA (Castellaci and Natera 2011) database and non-stationary econometric methodologies, namely the dynamic ordinary least-squares estimator (DOLS), Kao and Chiang (2000), to test for the existence of a long-run equilibrium relationship between the IPUs, Government and the Output. And following Monteiro (2013) evidence is threefold: (a) it shows the complementary and equally important role of the four helices for the innovation process. Innovation is there considered the growth engine and the outcome of the whole society in the framework of a one-sector economy; (b) public expenditures exert a very important economic role since an increase on them leads to an increase in the growth rate; and (c) technology infrastructures have also a positive influence on economic growth.

3.3 Descriptive Insights from the Group of OECD-23 Countries over 1980–2008

3.3.1 Data

Our sample spans over the period 1980–2008, for 23 OECD countries (henceforth OECD-23): Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, the UK and the USA.

We have used CANA database (2011), Castellacci and Natera (2011), since it was intended to overcome a major drawback in the applied field of NSI, for example, the inexistence of a reliable, suitable and coherent database covering the dimensions of the innovation process according to that framework of analysis. Six dimensions are considered in it, namely (1) innovation and technological capabilities; (2) education and human capital; (3) infrastructures; (4) economic competitiveness; (5) social capital; (6) political and institutional factors, see Castellacci and Natera (2011: pp. 34–40).

The variables chosen to test our models are the following: real GDP at constant prices in international dollars (Y), labour force (L), human capital (SH); government's productive expenditures: expenditure on education (ED), public expenditures on health (HE), public infrastructure expenditures (INF) and; and the product of the intermediate productive units (IPUs)—the output of universities and technological infrastructures and of firms: US patents granted per country of origin (PT), royalty and license fees payments (RY); specifically for technological infrastructures: telecommunication Revenue (TC) and Internet users per 1000 people (IT). Additionally,

Table 3.1 OECD-23 variables description

Variables	*Source*
PPP Converted GDP Per Capita (Chain Series), at 2005 constant prices. (rgdpch)—[Y/L]	PWT7.1
Population in millions. (pop)—[*POP*]	PWT7.1
PPP Converted GDP (Chain Series), at 2005 constant prices. (rgdpch x pop)—[Y]	PWT7.1
Number of persons engaged (in millions). (emp)—[*L*]	PWT7.1
Mean years of schooling. Average number of years of school completed in population over 14. (ge2es10sm)—[*SH*]	Barro and Lee (2010); World Bank
Public Expenditure on Education. Current and capital public expenditure on education. (ge1es12ec)—[*EDU*]	UNESCO
Royalty and license fees payments. Payment per authorized use of intangible, non-produced, non-financial assets and proprietary rights and for the use, through licensing agreements, of produced originals of prototypes, per GDP. (x3di1royag)—[*RS*]	World Bank
US Patents granted per Country of Origin. Number of utility patents granted by the USPTO by year and Inventor's Country of Residence per inhabitant. (x2di6pat)—[*US*]	UNESCO
Gini Index. Measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. Index ranging from 0 (perfect equality) to 100 (perfect inequality) (sc8ginii)—[*GN*]	United Nations
Feeling of Happiness. Index ranging from 3 (very happy) to 0 (not happy). (pt3sc24happf)—[*HP*]	World Values Survey
Most people can be trusted. Percentage of respondents who "agree" with this statement. (sc20trust)—[*TU*]	World Values
Civil Liberties. People's basic freedoms without interference from the state. It ranges from −7 (low freedom) to −1 (total freedom). (l2pf13ci1)—[*CL*]	Freedom House
Freedom of Speech. Extent to which freedoms of speech and press are affected by government censorship, including ownership of media outlets. Index from 0 (Government censorship) to 2 (No Government Censorship). (l3pf8prefh)—[*FS*]	Cingranelli and Richards (2008)

Source: Data from different sources was retrieved from CANA 2011 with the exception of rgdpch, pop and emp that were retrieved from PWT 7

Note: Our notations are in square brackets and those from the sources are in round brackets

we have considered competitiveness variables such as openness (OPEN) and domestic credit by banking sector (FDEV); political and institutional variables such as civil liberties (CL) and freedom of speech (FS); and social capital variables such as the Gini coefficient (GINI), feeling happiness (HP), and trust (TU),[1] see Table 3.1.

3.3.2 Insights from the OECD-23 Countries Database 1980–2008

Our OECD-23 sample only includes developed countries and all share characteristics of innovation economies suited to test the Quadruple Helix Innovation Systems Conceptual Framework. Nonetheless, this group of countries reveals a certain degree of heterogeneity that deserves our attention and might condition our econometric strategy. The statistics summary, Table 3.2, points out to a high level of volatility concerning variables GN and TU and to a lesser degree RY.

One way to point out to heterogeneity between OECD-23 countries is to look at the income dynamics of the group trying to ascertain whether income distribution is unimodal or multimodal and how it has evolved over time. Growth literature, namely about cross-country real income per capita differences (e.g. convergence, convergence clubs), is well aware of income dynamics methodologies suited to investigate the topic, Quah (1996, 2014). Under that framework subgroups of countries might be attracted to different steady-state equilibriums conditioned by income per capita thresholds what might indicate that lower income groups are subject to specific mechanisms, Azariadis (1996), Sachs et al. (2004) and or lack a suitable arrangement of institutions perpetuating in its absence a lower and stable steady-state growth equilibrium, Acemoglou (2009).

Table 3.2 Statistics Summary

Series	*Obs.*	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Y	667	26.79	1.255	24.631	30.205
L	667	15.939	1.195	12.519	18.863
SH	667	2.255	0.172	1.71	2.567
ED	667	5.273	1.19	1.891	9.102
PT	667	0.615	0.657	0.001	3.073
RY	667	1.086	1.505	−4.475	6.908
GN	667	30.491	5.177	18.5	46.408
HP	667	2.165	0.16	1.625	2.44
TU	667	0.391	0.3	0.1	0.74
CL	667	−1.427	0.78	−5	−1
FS	667	1.729	0.456	0	2

Note: *Series* denotes the name of the series; *Obs.*—the number of observations; *Mean*—series mean; *Std. Error*—the series standard error; *Minimum (Maximum)*—the minimum (maximum) value of the series

Figure 3.1 illustrates the distribution of income of the natural logarithm of real output (L_Y) at the initial and final years covered by our annual database (1980 and 2008) and two unimodal distributions are shown. When we compare both there is a slight shift to the right from 1980 to 2008 and also an increase of its concentration as well as of its right skewness. Figure 3.2 is built in the same vein as that of Fig. 3.1 but the variable of interest is instead the natural logarithm of real output per worker (Log (Y/L)), a better proxy for (direct) productivity since different country sizes are properly accounted for. Over time we observe a clear shift of the distribution to the right and an increase of its concentration. And we also notice that the 1980 multimodal distribution evolves towards a bimodal distribution in 2008. The latter shape is but a pale image of Quah's distribution, Quah (1993) but that is not surprising if we take into account that our sample, contrary to Quah's, only includes developed countries. But the shape resemblance between the two, points out to potential heterogeneity of the variables of interest (at least some) that characterize our group of innovation economies following the Quadruple Helix Innovation Systems Conceptual Framework.

To complement Figs. 3.1 and 3.2 we also represent the conditioned distribution of L_Y, Fig. 3.3, and Log(Y/L), Fig. 3.4, as continuous variables on the ordered variable time (Year).

Figure 3.3 gives us an image of L_Y evolution towards a bimodal distribution what was not so well perceptible in Fig. 1. The increase in the distribution concentration was also permanent over the period, according to Fig. 3.3, a phenomenon already accounted by Fig. 3.1.

Figure 3.4 shows an evolution from a multimodal distribution towards a bimodal one as well as a considerable increase in the concentration of the Log(Y/L) distribution. Ordinary time-series box-plot graphs were also plotted, Figs. 3.5, 3.6 and 3.7, accounting for the shape and evolution of the distributions associated to the variables retained in our second econometric model (see Sect. 3.4): L_Y; Log(Y/L); L_ED; L_SH; L_PT and L_RY.

The L_Y box-plot (Fig. 3.5) shows a distribution that is very concentrated over the interquartile 75–25 %; the median represented by the line in the box exhibits a smooth evolution over time and since the median is near the bottom line of the box, it suggests that the distribution is skewed right what is also corroborated by the fact that the ascending dashed lines have a higher length than the descending ones. Extreme values represented by balls are not observed. The Log(Y/L) box-plot confirms that the

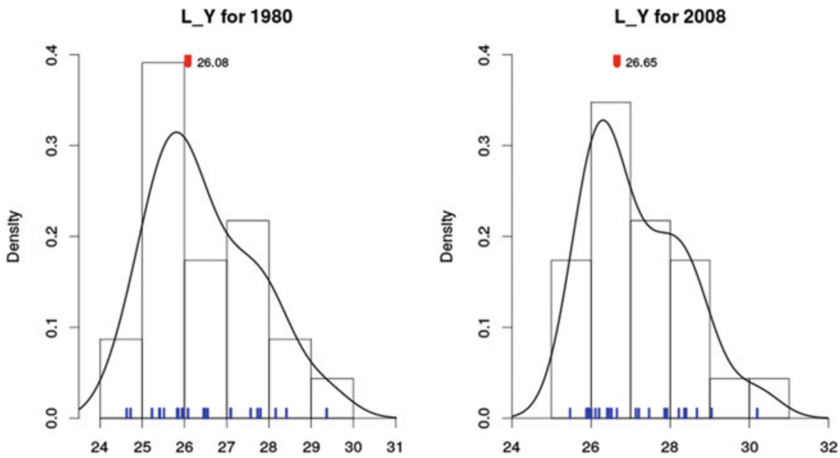

Fig. 3.1 Income Distributions for 1980 and 2008. *Note*: Fig. 3.1 is performed with the histogram and kernel estimates for L_Y in 1980 and 2008. The estimator used is the Rosenblatt-Parzen estimator with bandwidth following Sheather and Jones (1998) version, see Racine (2008), Li and Racine (2007) and Henderson & Parameter (2015). The value of the median is on top to the right of the red mark. The blue segments at the bottom reflect the concentration of data points

distribution is highly concentrated over the interquartile range and skewed left. The existence of extreme (low) values all over the time period is signalled by the balls indicating that countries with low levels of real output per capita exhibit a greater macroeconomic volatility as measured by this indicator.

Public Expenditure on Education, L_ED box-plot (Fig. 3.6), is very concentrated over the interquartile range and the median varies over time but it increases after 1998. High and low extreme values are observed over the period but the latter are further away from the minimum points, pointing out to public expenditure volatility on education by less-developed countries of our sample.

The number of patents, L_PT box-plot (Fig. 3.7), is not very concentrated over the interquartile range and the median increases modestly over time showing a decrease from 2000 to 2005 that is recovered in 2007 and 2008. Although the shape of the distribution seems to evolve over time, the median is situated at the upper part of the interquartile box what indicates a left skewness of the distribution.

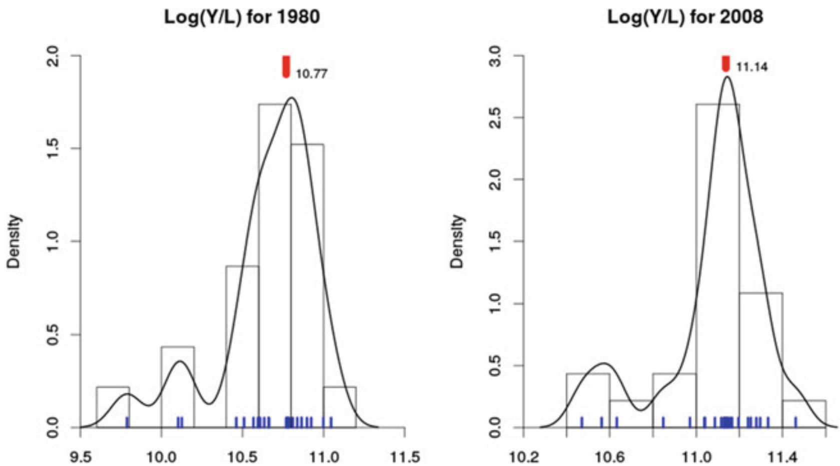

Fig. 3.2 Income per Worker Distributions for 1980 and 2008. *Note*: Fig. 3.2 is performed with the histogram and kernel estimates for Log(Y/L) in 1980 and 2008. The estimator used is the Rosenblatt-Parzen estimator with bandwidth following Sheather and Jones (1998) version, see Racine (2008, 2015) and Henderson & Parameter (2015). The value of the median is on top to the right of the red mark. The blue segments at the bottom reflect the concentration of data points

The amount of royalties paid, L_RY box-plot (Fig. 3.7), is very concentrated over the interquartile range and the median increases over time showing a pronounced decrease in 2002 but overthrown since 2004. Median registers a smooth evolution and a distribution shape almost unchanged until the first half of the 1990s after which the distribution narrows and the USA clearly emerges as outlier.

3.4 Empirical Model

3.4.1 Growth Regressions and Econometric Strategy

According to Rockey and Temple (2015) the seminal papers by Marris (1984), Kormendi and Meguire (1985), Baumol (1986), Barro (1991), Barro and Sala-i-Martin (1991) and Mankiw et al. (1992) gave rise to the research agenda on econometric growth empirics, whose importance has increased ever since. It covers a broad range of topics and exploits different cross-country (regions) data information in the framework of different types

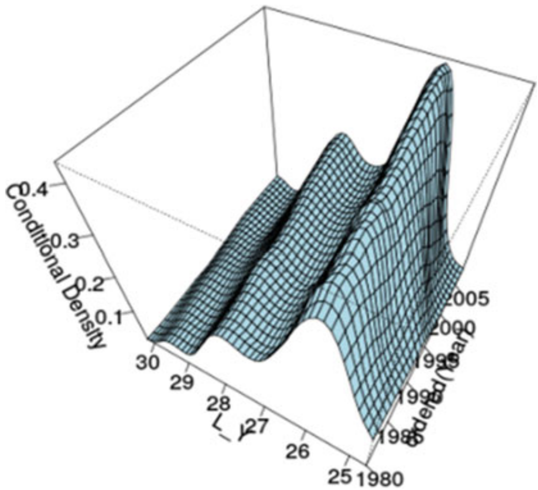

Fig. 3.3 Conditioned Distribution of L_Y over the Years. *Note*: The estimated bandwidth by likelihood and least-squares validation produce very low values for the continuous variable, which means an almost absence of smoothing, so we use the normal rule-of-thumb (Racine (2008), p.13) for this variable

of growth regressions and it addresses different econometric issues quite common to economic growth such as model uncertainty, parameter heterogeneity, endogeneity, measurement error and outliers, Durlauf and Quah (1999), Temple (2000) and Durlauf et al. (2004). Therefore, the search for robust methodologies to address model uncertainty, Sala-i-Martin et al. (2004), Moral-Benito (2012), and for consistent and efficient estimators to growth regressions turn out to be two major concerns within this literature, Durlauf et al. (2007), and undoubtedly accelerated macropanel econometrics research for stationary panel data Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998), Bond et al. (2001), and more recently for non-stationary panel data (see Eberhardt and Francis 2011).

Cross-country panel studies have become most popular in growth empirics after the mid-1990s overcoming shortcomings of cross-sectional studies that were dominant at the time econometric growth empirics was giving its first steps. Panel data takes into account temporal variation within and between countries contributing in this way to improve the efficiency of the estimators. Additionally, the issue of non-observable heterogeneity

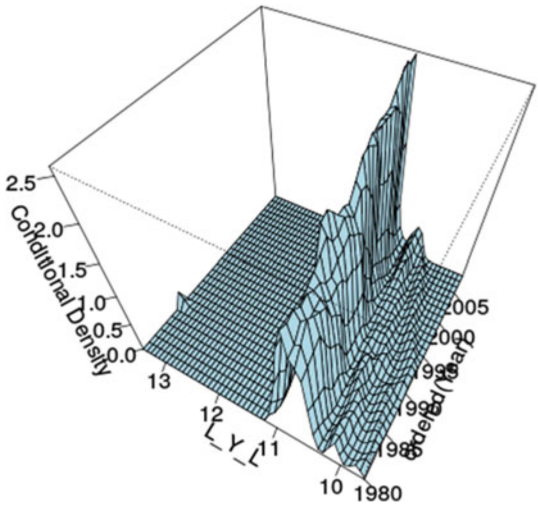

Fig. 3.4 Conditioned distribution of Log(Y/L) over time. *Note*: The estimated bandwidth by likelihood and least-squares validation produce very low values for the continuous variable, which means an almost absence of smoothing, so we used the usual rule-of-thumb (Racine (2008): p.13) for this variable

between countries and the associated omitted variable problem unsolvable using cross-sectional data is addressed with panel data and consistent estimators can be obtained. The other source of inconsistency and consequently of bias is the endogeneity of some of the RHS variables, that is, when the correlation of at least one of these variables with the error term is different from zero. According to Rodrik (2003), geography is the only production factor that by its one nature is an exogenous variable. Following the econometric strategies used by the authors above is worth mentioning that the estimators difference generalized method of moments (DIFF-GMM) and system generalized method of moments (SYS-GMM) have become very popular since they allow to address problems such as omitted heterogeneity and endogeneity in growth regressions.

Non-stationary panel econometrics emerged by the end of the 1990s and since then a growing theoretical and empirical literature developed, Pedroni (1999), Baltagi and Kao (2000), Baltagi (2001), and Breitung and Pesaran (2005). The critical review of the article of Coe and Helpman (1995) performed by Kao and Chiang (1999, 2000), and the article by Pedroni

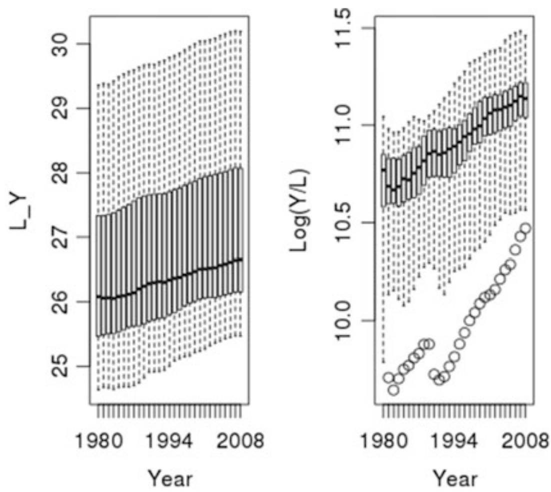

Fig. 3.5 L_Y and Log(Y/L) box-plots over time. *Note*: For each year the figure exhibits a box drop: that represents 50 % of the observations; the upper border represents percentile 75 % and the lower one the percentile 25 %. The box height represents the interquartile range (75–25 %); the line between them represents the median; the limit points at the dashed lines denote the minimum and the maximum values excluding outliers and the small balls the values greater (smaller) than three times the interquartile range

(2001) might be considered seminal empirical growth papers using non-stationary panel econometrics. Applied growth studies in this vein always perform a two-stage analysis. First, panel unit root tests are implemented in order to identify non-stationary panel series. If the null of panel unit root series is not rejected then, at the second stage (that might also be split in several other ones), appropriate models and estimators are usually applied to test for long-run equilibrium relationships as well as for short-run equilibrium relationships. Our empirical study falls in this line of research and its main econometric characteristics are spelled out below.

In order to test for the predictions of the QH one-sector endogenous growth model we first estimate the production function (Eq. 3.2). Our purpose is to verify the existence of a LR equilibrium relationship between variables and we made two important assumptions: (a) the intermediate goods produced by the IPUs, that are complementary inputs in the production function are represented by proxies of the IPUs output; (b) for the

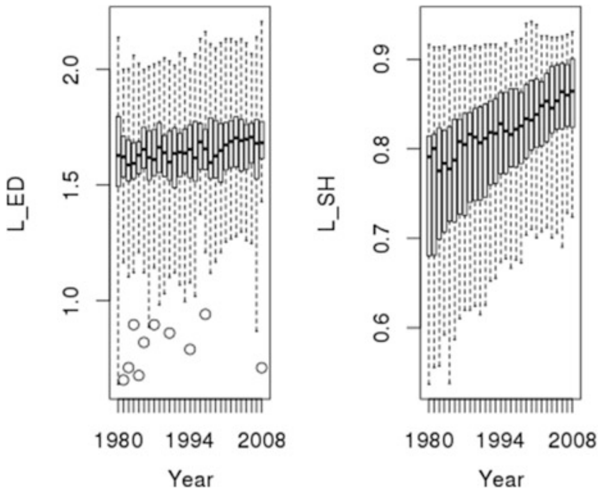

Fig. 3.6 L_ED and L_SH box-plots over time. *Note*: For each year the figure exhibits a box drop: that represents 50 % of the observations; the upper border represents percentile 75 % and the lower one the percentile 25 %. The box height represents the interquartile range (75–25 %); the line represents the median; the limit points at the dashed lines denote the minimum and the maximum values excluding outliers and the small balls the values greater (smaller) than three times the interquartile range

sake of comparative analysis and good equation specification, we start by modelling and estimating a very simple production function that only includes a small number of inputs (model 1, henceforth) and then we introduce more inputs suited to describe the QH one-sector production function (model 2, henceforth). We then focus on transitional dynamics by estimating short-run equations aimed at a twofold purpose: (a) to confirm cointegration relationships and (b) to test for weak causality in order to analyse different roles that might be played by variables in the short run due to the fact that variables might be or not influenced in the short run by long-run disequilibrium, in the former case variables are endogenous, in the latter case variables are weak-exogenous. We have estimated short-run equations associated to models 1 and 2 and we have considered two sets of variables: those that belong to the cointegration space and consequently are included as inputs in the LR production function specification and those variables that although not pertaining to the cointegration space are meaningful in

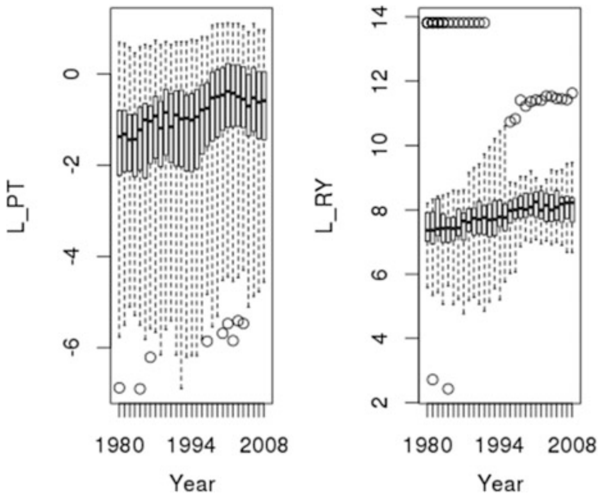

Fig. 3.7 L_PT and L_RY box-plots over time. *Note*: For each year the figure exhibits a box drop: that represents 50 % of the observations; the upper border represents percentile 75 % and the lower one the percentile 25 %. The box height represents the interquartile range (75–25 %); the line represents the median; the limit points at the dashed lines denote the minimum and the maximum values excluding outliers and the small balls the values greater (smaller) than three times the interquartile range

the Quadruple Helix Innovation Systems Conceptual Framework and influence the other variables in the short run.

We apply dynamic non-stationary panel methodologies with heterogeneous coefficients aimed to identify a long-run equilibrium equation (LR) and we use short-run equations (SR) to assess causality between the variables leading in this way to a better characterization of transitional dynamics towards long-run equilibrium and to differentiate the variables of interest in terms of weak-endogeneity or endogeneity. We build a three-step econometric analysis and start by testing panel series stationarity using panel CADF tests following Costantini and Lupi (2013). In the second step we estimate a LR equation by applying DOLS with heterogeneous coefficients, Pedroni (2004, 2000 and 2001) which allow us to address the issue of endogeneity. And finally, we estimate the error corrector mechanism (ECM) by using a mean group aggregation on individual equations in order to confirm cointegration relationships Engle and Yoo (1987) and to perform causality analysis by distinguishing between endogenous and weak-exogenous variables, that is the short-run evolution of the variable is independent of long-run disequilibrium.

We start by testing panel series stationarity using panel CADF tests, both with and without a trend. The null hypothesis (H0) of the tests is the presence of a unit root in all series against the alternative that at least one of the series is stationary. In order to correct for cross-sectional dependence between individuals as defended by Costantini and Lupi (2013) following Hartung (1999) and Demetrescu et al., (2006), we use the test version by Demetrescu et al. (2006) with and without trend. We also test the covariate augmented Dickey-Fuller test (CADF) proposed by Costantini and Lupi (2013) and based on (Hansen 1995) and (Hanck 2013). When compared with the ordinary ADF panel test it shows a power test gain if a stationary variable is included in the augmented equation, as was demonstrated by (Hansen 1995). (Costantini and Lupi 2013) suggest the average of the first difference applied to all individuals or the first difference of the first principal component of the variable to be used as a stationary variable. In order to also correct for cross-sectional dependence in both tests a significance level is required by the (Pesaran 2004) test to be less than a typical value and the 10 % level is considered to be an acceptable choice. So we use the pCADF tests with and without trend by (Hartung 1999) and (Demetrescu et al. 2006) that automatically correct for cross-sectional correlation assuming a threshold of 10 % and as covariate the first difference of the variable under study. These four tests will be identified by Zh, Zh(t), pCADF and pCADF (t), respectively, where (t) stands for the presence of a trend.

At a second stage of our econometric analysis we estimate LR equilibrium equations by using the estimator DOLS with heterogeneous coefficients, Pedroni (2004, 2000, 2001). Since the variables under analysis are non-stationary, in this case integrated of order one, the model is rendered dynamic by adding lags and leads of order s of the first difference of the independent variables, ΔX, and we considered s=1.

$$Y_{\mathrm{it}} = \alpha_i^{\mathrm{LR}} + X_{\mathrm{it}}^{'}\beta_i^{\mathrm{LR}} + \sum_{l=-s}^{s} \Delta X_{\mathrm{it}-l}^{'}\phi_{\mathrm{il}} + \mu_{\mathrm{it}} \tag{3.3}$$

Υ is a (NTx1) vector of the dependent variable; α^{LR} is a (NTx1) vector of the LR constants; X' is the (NTxk) matrix of the k dependent variables; β^{LR} is a (kx1) vector of the LR coefficients of the RHS variables; ΔX is an [NTxk] one lag and one lead of the RHS variables in first differences and ϕ_l is a [kx1] vector of the coefficients of the above mentioned variables; and finally, μ is the (NTx1) error term vector.

At the third and final stage of our econometric analysis we started by defining and estimating the dynamic short-run equations based on Eq. (3.3):

$$\Delta Y_{i,t} = \alpha_i + \lambda_i \cdot \mathrm{ECM}_{i,t-1} + \sum_{h=1}^{m} \Delta X^{'}_{i,t-h}\theta_{i,h} + \sum_{h=1}^{m'} \Delta Y^{'}_{i,t-h}\gamma_{i,t-h} + Z^{'}_{i,t}\upsilon_i + \varepsilon_{i,t} \tag{3.4}$$

$$\Delta X^{k}_{i,t} = \alpha_i + \lambda_i \cdot \mathrm{ECM}_{i,t-1} + \sum_{h=1}^{m} \Delta X^{'}_{i,t-h}\theta_{i,h} + \sum_{h=1}^{m} \Delta Y^{'}_{i,t-h}\gamma_{i,t-h} + Z^{'}_{i,t}\upsilon_i + \eta_{i,t} \tag{3.5}$$

$$\mathrm{ECM}_{i,t-1} = Y_{i,t-1} - \alpha_i^{\mathrm{LR}} - X^{'}_{i,t-1}\beta_i^{\mathrm{LR}} \tag{3.6}$$

Notice that the variables included in the Z matrix are outside the cointegration space but probably influence the short-run equilibrium. We have simplified our estimations by imposing a lag polynomial of degree one and assumed heterogeneity of all the coefficients. Then, after having confirmed the existence of cointegration relationships between variables, we addressed the causality issue based on the concept of weak-exogeneity. Finally we analyse short-run causality.

3.4.2 Results

The results of the 4 panel unit root tests: Zh and Zh(t) and pCADF and pCADF(t) applied to 10 of the 12 variables in levels are shown in Table 3.3. For variables L_Y, TC, L_L, L_PT and L_SH with drift we cannot reject the presence of a unit root in all series against the alternative that at least one of the series is stationary. The same tests were also applied to those variables in first differences and the results confirm that those variables are stationary in first differences.[2] The null hypothesis is also rejected for the variables TU, HP; L_RY, L_ED and GN.

Notice also that all these tests correct for cross-sectional dependence which constitutes a source of bias leading to inefficiency of the estimates. The presence of cross-sectional dependence (TRUE) or its absence

Table 3.3 Panel Unit Root Tests

TESTS VARS.	*Zh*	*Zh*(t)	*pCADF*	*pCADF*(t)
L_Y	1.920	0.562	1.360	−1.270
	TRUE	TRUE	TRUE	FALSE
L_L	2.557	0.531	1.784	−0.736
	TRUE	TRUE	TRUE	TRUE
L_SH	−0.639	−6.547***	0.204	−6.610***
	TRUE	TRUE	TRUE	FALSE
L_ED	−3.613***	−2.299**	−3.750***	−8.765***
	TRUE	TRUE	FALSE	FALSE
L_PT	0.134	0.923	−1.567	−0.671
	TRUE	TRUE	TRUE	TRUE
L_RY	−3.543***	−3.025***	−4.510***	−6.11***
	TRUE	TRUE	TRUE	TRUE
GN	−7.208***	−6.241***	−9.047***	−7.945***
	TRUE	TRUE	FALSE	FALSE
HP	−6.37***	−11.16***	−6.91***	−13.30***
	TRUE	FALSE	TRUE	FALSE
TU	−3.831***	−2.657***	−7.938***	−9.627***
	TRUE	TRUE	FALSE	FALSE

Notes: *Z* and *Z*(*t*) are panel ADF tests with cross-sectional correction, with drift and trend (*t*); pCADF and pCADF(*t*) are panel ADF tests with cross-sectional correction and the first difference of the variable is used as covariate, with drift and trend (*t*); VARS. denotes variables; (***), (**), (*) denotes significant level at 1 %, 5 % and 10 %, respectively. TRUE indicates detection and correction of cross-sectional dependence and FALSE denotes the opposite.

(FALSE) is reported in the results. It is worth mentioning that the variables FS and CL were not submitted to the above panel unit-root tests due to their nature of discrete variables.

Based on the results exhibit in Table 3.3 we conclude that five of our variables are panel non-stationary in levels, so we apply suitable non-stationary panel econometric estimators and models to our data. We estimate the LR equilibrium Eq. (3.3) using model 1 (see Eqs. (3.7) and (3.8) below, respectively).

$$\begin{aligned}\text{Model 1}: \mathrm{L\_Y}_{it} &= \alpha_i^{\mathrm{LR}} + \beta_{i1}^{\mathrm{LR}}\mathrm{L\_L}_{it} + \beta_{i2}^{\mathrm{LR}}\mathrm{L\_ED}_{it} + \phi_{i1,-1}\Delta\mathrm{L\_L}_{it-1} \\ &+ \phi_{i1,+1}\Delta\mathrm{L\_L}_{it+1} + \phi_{i2,-1}\Delta L\_\mathrm{ED}_{it-1} + \phi_{i2,+1}\Delta L\_\mathrm{ED}_{it+1} + \mu_{it}\end{aligned} \tag{3.7}$$

$$\text{Model 2} : \mathrm{L\_}Y_{it} = \alpha_i^{LR} + \beta_{i1}^{LR} L\_L_{it} + \beta_{i2}^{LR} L\_ED_{it} + \beta_{i3}^{LR} L\_RY_{it} + \beta_{i4}^{LR} GN_{i4} + \beta_{i5}^{LR} L\_SH_{it} + \beta_{i6}^{LR} L\_PT_{it} + \sum_{l=-s}^{s} \Delta X'_{it-l} \phi_{il} + \mu_{it} \tag{3.8}$$

the matrix ΔX contains leads and lags of order one of: L_L , L_ED , L_RY , GN , L_SH and L_PT in first differences.

Model 1 is a baseline model where we have considered a production function with only two inputs (raw) labour and education expenditures in order to take into account government's role in the provision of human capital, a key and crucial input factor in the framework of the Quadruple Helix Innovation Systems Conceptual Framework. Model 2 extends model 1 by also including as inputs the outcome of the IPUs in this case royalties and license fees payment (L_RY) and US patents granted for country of origin (L_PT) and mean years of schooling is the proxy for human capital incorporated in the labour force (L_SH); productive expenditures by the government continue to be proxied by current and capital public expenditure on education (L_ED); the Gini coefficient that measures the deviation of the distribution of income among individuals or households within a perfect equal distribution (GN) is taken as a proxy for social capital.

The expected theoretical sign for all the variables is positive except for the Gini coefficient that is expected to be negative, Knack and Keefer (1997), Zak and Knack (2001), Perotti (1996). It is worth mentioning that we only retained the models with a good fit and with statistical significant coefficients at the usual levels for all variables and that this procedure is also extended to short-run models.

Table 3.4 shows evidence of long-run equilibrium relationships between output and the RHS variables in both models that also present the expected signs and statistical significance for all the estimated coefficients but model 2 is preferable to model 1 because the deviations of the long-run relationship are smaller. It is worth mentioning that the IPUs' coefficients are positive (L_SH, S_RY and L_PT) as well as government's coefficient what confirms the equally important role of the four helices for output production. However we could not confirm the importance of technological infrastructures as such because none of the proxies used were statistically significant under the framework of model 2. Finally, the negative sign of the Gini coefficient points out to the existence of a positive relationship between social capital and output what is in line with the related literature.

We have estimated ECM equations or SR Eqs. 3.4 and 3.5 associated to model 2 without and with variables included in matrix Z, the latter case corresponds to the augmented SR equations. We already know that the matrix X of the RHS variables might include variables L_L , L_ED , L_RY , GN , L_SH , L_PT and ΔX is also defined above. The set of variables included in matrix Z are political-institutional variables, civil liberties, (CL); freedom of speech, (FS) and social capital variables feeling of happiness, (HP),[3] Castellacci and Natera (2011). They lay outside the cointegration space so they do not influence the LR equilibrium of the economy, nonetheless those variables influence the short-run equilibrium relationships as it is shown in Tables 3.5 and 3.6.

If we turn to the cointegration results from Tables 3.5 and 3.6, we observe that in model 2, L_PT is weak-exogenous in the non-augmented version as well as L_SH, so the SR dependent variable is not influenced by the LR disequilibrium relationship between the variables included in the ECM and all the remaining variables are endogenous. Although PT is

Table 3.4 Long-Run Equilibrium Equations (DOLS with heterogeneous coefficients)

Variables	*Model 1*	*Model 2*
LHS variable	L_Y	L_Y
RHS variables		
constant	*9.960*	*8.016*
	(11.942)	(13.803)
L_L	*1.039*	*1.045*
	(62.129)	(178.567)
L_ED	*0.219*	*0.436*
	(10.691)	(83.091)
L_RY		*0.026*
		(9.444)
GN		*−0.004*
		(131.312)
L_SH		1.078
		(359.264)
L_PT		0.067
		(22.301)
see*	0.339	0.307
Individuals	23	23
Time periods	29	29
Dynamic lags	1	1

Note: See* it is the square root of the sum of error correction terms (ecm_s) squared divided by NxT; *N* number of individuals, *T* number of time periods, *t* Statistics are in brackets

Table 3.5 Short-Run and Augmented Short-Run Equilibrium Equations Associated to model 2

RHS variables	*DL_Y*		*DL_L*	*DL_ED*	
Constant	0.018***	–0.038	0.001	–0.010	0.442*
ECM{1}	–0.028**	–0.031***	0.075***	0.136***	0.201***
DL_L{1}	–0.325***	–0.322***	0.231***		
DL_Y{1}	0.420***	0.411***			
DL_ED{1}				–0.315***	–0.304***
DGN{1}					
DL_SH{1}					
DL_PT{1}	0.013**	0.014**			
DL_RY{1}	0.011**	0.010**			
CL					
FS		0.028**			
HP					–0.189*
Usable observations	621	621	621	621	621
Degrees of freedom	615	614	618	618	617
R^2	0.36	0.39	0.23	0.16	0.22

Linear Regression Estimation by Pooled Mean Group
Note: R^2 represents the coefficient of determination, it is the mean of the R^2 individuals; (***), (**) and (*) represent levels of significance at 1 %, 5 % and 10 % respectively

weak-exogenous in the non-augmented equation, its values are explained by the LR disequilibrium when social capital variables are included such as CL and FS. We thus conclude that only SH is weak-exogenous. So, except for the late variable all the remaining variables included in the LR model are mutually dependent in the LR and in the SR.

Comparing the results from the estimation of the two versions of Eqs. (3.4) and (3.5) we conclude that for all pairs of equations the same one-lagged difference variables are included and the estimates are quite similar.

If we look at the estimates of the RHS first difference variables registered in Tables 3.5 and 3.6 we can analyse SR short-run dependence between variables. L_Y depends on its lagged behaviour, on the SR behaviour of L_ED, L_PT and L_RY. As for L_L, L_ED, L_SH and DGN they depend only on their past behaviour. In turn, L_PT is influenced in the SR by itself by L_ED and L_RY. Finally, L_RY depends on itself and on L_SH for both versions of Eq. (3.5) and also on L_L in the case of one version of Eq. (3.5). Additionally, the variable L_Y is influenced in the SR by freedom of speech (FS) and L_ED is influenced by feeling happy, HP.

Table 3.6 Augmented Short-Run Equilibrium Equations Associated to model 2 (cont.)

LHS variable	*DL_PT*		*DL_RY*		*DL_SH*	*DGN*
RHS variables:						
Constant	0.010	−0.543***	0.268**	0.240**	0.004***	−0.165
ECM{1}	0.163	0.287**	0.878***	0.761***	0.009	−3.554***
DL_L{1}			3.034			
DL_Y{1}	1.77***	1.721***				
DL_ED{1}						
DGN{1}						0.285***
DL_SH{1}			12.794***	12.958***	−0.281***	
DL_PT{1}	−0.315***	−0.355***				
DL_RY{1}	0.134***	0.111***	−0.187***	−0.216***		
CL		−0.107***				
FS		0.216**				
HP						
Usable observations	621	621	621	621	621	621
Degrees of freedom	616	614	616	617	618	618
R^2	0.26	0.34	0.21	0.18	0.13	0.17

Linear Regression Estimation by Pooled Mean Group
Note: R^2 represents the coefficient of determination, it is the mean of the R^2 individuals; (***), (**) and (*) represent levels of significance at 1 %, 5 % and 10 % respectively

Short-run behaviour of our variables L_Y, L_ED and L_PT is also influenced by political-institutional variables such as CL, FS and HP. For example, freedom of speech, FS, positively influences L_Y in the SR as well as L_PT. Thus, civil liberties, freedom of speech and feeling happiness speed up the adjustment of the economy towards LR equilibrium values through their influence on the SR dynamics of the variables L_Y, L_PT and L_ED that belong to the cointegration space.

These results point out to the importance of political-institutional variables as well as for social capital ones for the explanation of the short-run behaviour of the variables of the cointegration space.

3.5 Concluding Remarks

The Quadruple Helix Innovation Systems Conceptual Framework, Liljemark 2004, Khan and Al-Ansari (2005) on NSI constitutes a development of the Triple Helix Innovation Systems Conceptual Framework since it considers a new actor—the civil society, performing the role of the fourth helix in the innovation process that is characterized by the interplay between universities and technologic infrastructures, government and companies to create new ideas useful for the society (Etzkowitz and Leydesdorff 2000; Etzkowitz and Klofsten 2005).

Quite recently Afonso et al. (2012, 2014), started a new line of research about QH theory by modelling it in the framework of R&D growth models, a very promising approach since Quadruple Helix Innovation Systems Conceptual Framework predictions are obtained in a rigorous way and consequently can be tested using several applied methodologies. Monteiro (2013) presents the first attempt to empirically test the long-run equilibrium relationship from the first QH-R&D growth model by Afonso et al. (2012) with the help of non-stationary panel techniques using homogenous DOLS for a sample of 24 OECD countries, between 1980 and 2008 and the main predictions of the model were not rejected.

Our empirical study also tests the main predictions of Afonso et al. (2012) model for a sample of 23 OECD countries over the same time period and the main predictions are also confirmed. Our applied analysis makes use of non-stationary panel techniques and contributes to the literature in several ways. It addresses the issue of coefficient heterogeneity. By applying cointegration techniques we are also able to identify long-run and short-run equilibrium relationships and to distinguish balanced growth from transitional dynamics. This methodological strategy allows us to better identify the roles that the variables at stake play in the long- run and short-run equilibriums. More specifically, by distinguishing those variables that belong to the cointegration space from those that are out of it, by identifying those variables that in the short-run are not influenced by the long-run disequilibrium (weak-exogeneity causality) and also by identifying short-run causality between variables. By performing this triple variable identification we are not only better equipped to test for QH policy predictions but also to provide more accurate QH policy recommendations.

Our long-run equilibrium model identifies the following variables that fall in the cointegration space and thus contribute to the long-run equilibrium according to Quadruple Helix Innovation Systems Conceptual Framework predictions: L_L and L_SH; L_ED; L_PT and L_RY; and GN. The first two variables represent the accumulation of raw labour and human capital; the second government expenditures; the third and fourth the product of the IPUs and the last one society. And we have proved that government, the IPUs and society contribute positively to balanced growth.

From the short-run equations we identify the following weak-exogenous variables: the IPUs product and human capital. Nonetheless, in the former case the variable becomes endogenous because its values turn out to be explained by long-run disequilibrium when political and institution variables such as civil liberties and freedom of speech are taken into account. So we can conclude that only education is weak-exogenous and that the remaining variables that belong to the cointegration space are mutually interdependent both in the long and short run.

The short-run behaviour of almost all the variables pertaining to the cointegration space are also influenced by political and institutional variables such as civil liberties, freedom of speech and by social capital variables such as feeling happiness. Thus we find evidence that these types of variables exert a positive effect upon the speed of adjustment during the transitional dynamics. The Gini coefficient a proxy for society, one of the four helices, is the unique social capital variable that belongs to the long-run equilibrium relationships. It is related negatively to output what means that more inequality is harmful to the innovation process and thus to economic growth. Government expenditures contribute positively to long-run equilibrium output meaning that this helix plays its role in the innovation process according to the theory and consequently is growth enhancing. Furthermore, due to the variables that pertain to the long and short run as well as to the long-run and short-run equilibrium relationships we confirm that there is an accrued room for policy making by the government through R&D policies that enable an adequate functioning of the four helices leading to growth as well as through social and institutional policies that foster the transitional dynamics of the economy.

Notes

1. It should be mentioned that the variables public expenditures on health (HE), public infrastructure expenditures (INF), telecommunication revenue (TC), Internet users per 1000 people (IT); openness (OPEN) and domestic credit by banking sector (FDEV) turn out to be statistically insignificant in the models we estimated. Those results are not reported but are available upon request from the authors.
2. The results are available upon request from the authors.
3. The variable trust (TU) turn out to be excluded from the augmented version of the SR equations because model fit measured by the standard error of the estimation has worsened with TU inclusion.

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CHAPTER 4

How Rationales, Actors and Multi-Level Governance Relate to Innovation Policy-Mix

Manuel Laranja

4.1 Introduction

Innovation policy is a complex process resulting in a policy-mix composed of multiple objectives, policy strategies, policy instruments and programmes, oriented towards different actors and implemented by different jurisdictions at different governance levels. Taken altogether the policy strategies, objectives, justifications and segmentation according to constituencies and governance levels, as well as their interactions and interdependencies (Magro and Willson 2013, p. 1654), define what we would call a dynamic innovation policy-mix. In this chapter we attempt to develop a multi-dimensional policy space that may help to enhance our understanding of innovation policies. We propose to explore the following three different dimensions:

First, the balance associated with the mix of rationales for public intervention. We consider theoretical rationales and policy ideas. All these different types of rationales may condition or determine specific forms of public intervention in a broad range of policy domains pertaining to innovation policy. Contrasting different types of rationales will help to

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understand how specific policies and associated instruments are justified and what is expected in terms of results and impacts.

Second, we will explore the multi-actor mix in terms of policy targets. That is, how the increasing diversity of new and old types of actors in the innovation system should be taken in consideration in the design of a policy-mix. The contrast between instruments oriented towards different types of actors versus systemic instruments envisioning networking and systemic aspects of innovation will also be considered.

Third, we will explore the multi-level mix, associated with the political and territorial scale of policy actions, as well as the policy scope at each level, including governance aspects of multi-level innovation policy.

4.2 The Mix of Rationales

Rationales are the reasons (spoken or written in policy documents) used by policy makers to justify public intervention. Because rationales contain assumptions about the nature of the system within which an intervention is to be made, they implicitly or explicitly problematize and justify the need for intervention, outline the logic through which that policy intervention is expected to lead to the intended outcomes and, to a considerable extent, determine the types of policies and instruments adopted and implemented in practice (Laranja et al. 2008). Uncovering the theory and the rationales behind policy action or inaction is therefore essential if we want to understand innovation policies (Salmenkaita and Salo 2002).

In our approach we see at least two kinds of rationales shaping innovation policy-mixes: theoretical rationales justified through concepts and theories; and ideas that is, visions of why and how to make and effect policy action.

4.2.1 Theoretical Rationales

Theoretical rationales are those derived from specific concepts and theories which arguably inform the design and implementation of specific policies (Bach 2006). Although scholars in Political Science see policies as the outcome of a process influenced by stakeholders' interests, interactions and power relations, studies in the broad multi-disciplinary area of Science, Technology and Innovation (STI), deal almost exclusively with "theoretical rationales". By and large, STI studies, produce only broad general principles and taxonomies for policy (Teubal 2002; Abramovsky et al. 2004; Borrás 2009; Metcalfe 1995). Laranja et al. (2008) argued that in

STI studies, innovation policy is almost invariably treated as an additional exogenous element of the innovation system, and that it is often assumed that concepts produced by different theories and frameworks are automatically accepted, used by the policy-making community (policy makers, advisors, intermediaries, etc.) and easily translated or transferred into specific policies.

While the dominance of the linear model and the "market failure" neoclassic approach to innovation policy (Howlett and Ramesh 2003) may suggest that concepts from theory can be easily adopted by the innovation policy community and translated into policies and instruments, recent alternative rationales such as "learning failures" or "institutional failures" coming from evolutionary economics, systems of innovation (Llerena and Matt 2006) or the triple and quadruple helix (Etzkowitz 2003; Carayannis and Campbell 2010) are perhaps much more difficult to transfer into concrete policies.

For example, numerous references to models of systemic innovation (national, regional and sectoral), can today be easily found in official documents of the European Union (EU) or in innovation policy agendas of many European countries. However, though concepts from evolutionary and systemic theories of innovation permeate policy discourse, implementation through adequate "instruments" is much less common (Smits and Kulhman 2004). The most common innovation support instruments today are still grants and tax incentives to research and development (R&D), usually justified as compensations for less than optimal investment in innovation from the private sector, that is the neoclassic policy argument.

In addition we may add that, although a particular policy may be justified by one rationale, the corresponding implementation through instruments and programmes often does not follow the same rationale. For example innovation policy instruments that support placement of qualified human resources in small- and medium-sized enterprises (SMEs) can be justified using the learning failure argument. However, their implementation often relies on contacts-lists and simple matching schemes, that is without previous detailed screening of SMEs needs and of candidate profiles, hence following a rather neoclassical market information failure rationale.

4.2.2 Inspiring Ideas and Practices from Elsewhere

Rationales as justifications for policy are not, however, necessarily based on theories and conceptual models. As mentioned before, scholars of STI tend to assume that concepts and theories that they produce are easily accepted and used by the policy-making community. Usually they overlook policy transfer that is, the process by which knowledge about policies, administrative arrangements, institutions and ideas in one political system (past or present) is used in another political system (Dolowitz and Marsh 2000, p. 5). As in other domains, innovation policy ideas and policy makers' own processes of learning, imitation and experimentation may play a significant role (Mytelka and Smith 2002). The term policy-idea refers to "specific policy alternatives as well as the organized principles and causal beliefs in which policy proposals are embedded" (Béland 2005).

If on the one hand pressures exerted by global social and economic forces produce common innovation policy problems and incentivates imitation and share of common policy solutions (Bennett 1991; Drezner 2001; Holzinger and Knill 2005), on the other hand, a growing international industry of consultants and academics in innovation policy, together with information on successful policy instruments and programmes being increasingly digitized, indexed and made accessible through the internet at limited effort for minimal cost, also strongly contribute to rapid spread of the same policies and their rationales in different contexts (Legrand 2012).

There are many examples of rationales that apparently may be just "spontaneous" transfer of ideas from elsewhere. The rapid spread of techno-science parks and incubators in Europe in the 1980s and 1990s is one example (Massey et al. 1991). The recent interest of regional authorities on cultural and creative industries (Flemming 2008) or in Entrepreneurial Ecosystems (Mason and Brown 2013) can perhaps be explained by the transfer of policy ideas across countries, supported by international consultancy and international ranks such as WEF (2013). The wide acceptance of the Organisation for Economic Co-operation and Development (OECD) model of policy coordination, planning, budgeting priority-setting and so on, in science policy is another example of the important role that international organizations may play in the spread of policy ideas and specific programmes (Henriques and Laredo 2013).

Because acceptance and transfer of policy ideas may depend on factors other than their own merits, bad ideas can be as influential as good ones and in fact questions of why, how and when certain types of transfer appear in particular settings and not others, have still not been fully addressed. Among factors that promote policy-ideas-transfer and adoption we highlight the following (Dolowitz and Marsh 2000).

First, the success of policy-ideas acceptance and transfer may be related to pre-existing beliefs to judge new ideas (including ideologies). In this sense, past policy experiences (of both success and failure) may play a most important role in opening up or closing policy makers' acceptance to transfer and learning of imported ideas.

Second, transfer and adoption of policy ideas appears to share with evidence-based policy (Perry 2002) a similar focus that is the search about what works. Inspiring policy success stories occurring elsewhere may therefore be stronger drivers when compared to different kinds of evidences or with the conceptually rich literature on STI studies.

Third, innovation policy transfer may also be related to governance that is how support from groups of interest and how the intermediary agencies and institutions play their role as mediators and policy-executives during the design-imitation-implementation process.

Finally, we need a better understanding of what is transferred and accepted. Often the final outcome may not resemble the idea which triggered the acceptance of the "new" policy in the first place. Also, is it just the policy goals, or does the transfer include policy content, policy instruments, policy programmes and so on?

4.3 The Multi-actor Mix

The second dimension of the innovation policy-mix that we consider is associated to different types of actors that compose the innovation system and to their interactions. The wider perspective on innovation policy that we find today in many countries also means that we need to consider a wider set of actors, including not only public and private technology infrastructures, universities and enterprises but also different kinds of associations and less formalized groups of actors organized in clusters of firms in related sectors. Also, the more participatory character of policy making in general, has contributed to a specialization of policies specifically oriented towards different groups of actors.

In the following we suggest possible ways to "segment" innovation policies and policy instruments oriented to private sector firms according to their innovation capabilities and to combine these with policies that may help to strengthen the systemic aspects of innovation.

4.3.1 *Policies for Different Innovation Capability Levels*

The multi-actor innovation policy-mix can be designed assuming that not all firms have the same "innovation capabilities" that is, capabilities to articulate product development, production and delivery and to discover new business models (Pisano and Shih 2012). For example, we cannot assume that R&D incentives (tax and subsidies) are equally effective for any kind of public or private sector actor, and in particular that all kinds of enterprises will benefit from R&D incentives.

The innovation literature suggests different alternatives to classify firms according to their levels of innovation capability (Laranja 2009). Older classifications such as that of Vernon (1988), inspired by the seminal work of Pavitt (1984), or the one used by Rothwell and Dodgson (1989) in their study commissioned by Industrial R&D Advisory Committee of the European Commission, were updated by Clarysse and Duchêne (2000). However, Arnold and Thuriaux (1997) have probably been the first to explicitly suggest the use of innovation capabilities levels to "segment" innovation policies in a particular region.

For example, at sub-national levels some regions may display a "flat capability structure" characterized by a higher number of small companies with limited or no qualified human resources for the practice of innovation and R&D that is, companies with lower innovation capabilities. For regions with such a reduced capacity for innovation, the innovation policy-mix cannot be the same as in regions that have higher numbers of organizations involved in R&D and innovation. Small firms, with reduced capabilities usually experience greater difficulties in making use of public resources and incentives available. Innovation policies using instruments such as information awareness campaigns, public consultancy services for problem diagnosing or for help in finding adequate specialized suppliers, would probably be most effective for firms with low innovation capabilities, while possibly augmenting the effectiveness of standardized instruments such as incentives to R&D and innovation.

Interesting examples of innovation policy instruments targeted at firms with lower capability levels are the Steinbeis Foundation in Baden Wurtenberg, or the IRAP programme running since 1948 in Canada (OECD 1997, pp. 72–72). Also, the "technology-clinics" in Finland (OECD 2002, p. 111; Diederen 1999) appear to suggest that adding "advice services" to the supply of funds and information for promoting collaboration, induces cognitive and behavioural changes in target firms and enhances the effectiveness of standardized instruments of support to investment in innovation. Finally, benchmarking and other schemes that facilitate systematic comparison with competitors, or schemes that provide supervised visits to best practice companies such as the "Inside UK Enterprise" set up by the DTI/UK may also be good examples of innovation policy instruments targeted at firms with lower innovation capabilities (Bridge and O'Neill 2009, pp. 442–447).

In contrast, regions with a higher proportion of companies at a medium level of innovation capabilities would probably focus on innovation policies targeted at the creation of interfaces and bridges with the local and non-local technology infrastructures and universities. This may involve designing effective programmes for R&D brokerage and formulating joint collaboration projects, or referral schemes to guide companies to adequate specialized services suppliers.

Finally regions with a high percentage of firms at higher levels of capability may perhaps choose to concentrate their multi-actor innovation policy-mix around instruments such as R&D support, tax incentives to R&D, mobility of qualified scientists and engineers and so on.

4.3.2 Systemic Policies

The multi-actor mix goes however beyond a segmented innovation policy approach, whereby specific instruments are aligned with innovation capability levels and must include complementary policies directed towards networking, interactive learning and systemic aspects of innovation. Innovation programmes and actions to facilitate and promote collective efforts and systemic effects are usually targeted not to specific actors, focusing instead on linkages and collaboration between different actors in the innovation system.

Examples of systemic policies include (Smits and Kulhman 2004): subsidized access to technology centres and institutes; support for technology transfer/brokerage (research-to-industry or firm-to-firm), including university liaison offices, patenting support services and so on (Laranja 2009).

It is important, however, not to take "system policies" as responses to information failures or to failures in creating market mediated linkages. System policies are not just support to contacts and networking. They are a support to interactive learning, and therefore may involve some kind of pro-active intermediation efforts.

4.4 The Multi-level Mix

The third dimension of our innovation policy-mix space is about the balance and articulation of policies at different political and territorial scales, namely European, national and sub-national/regional levels. It involves vertical governance issues such as the degree of autonomy given to intermediate authorities (regional agencies, local foundations, etc.) and, at each level, it involves defining which sectoral policy domains fall within the wide scope of innovation policies.

This multi-level policy balance of policies and instruments is, however, a subject of much debate. In the one hand, top-level articulation may create the opportunity for gaining economies of scale, avoid duplication of resources, hence taking advantage of the cumulative characteristics of science and technology. On the other hand, it may prevent diversity, local experimentation and localized policy learning and adaptation at sub-national levels, and in particular it may prevent the establishment of differentiated innovation strategies at the regional level.

4.4.1 Top-level Innovation Policies

In principle, some policies of the innovation policy-mix may be more efficiently offered at EU or at National levels than at regional or local levels. For example, resource efficiency policies in general such as lowering costs of the European patenting process, or even specific schemes that help to compare and exchange policy practices (policy benchmarking) in different regions and balance the tendency of regional stances to mimetically replicate programmes and objectives of national policies and of other regions, may be more efficiently tackled at a higher level.

In addition, innovation policies at the European level could play a central role in offsetting the flight of talent from less-favoured regions, to "excellent" regions with better working conditions and higher concentration of centres of research.

At the European and national levels, innovation policies are often taken as "umbrella" policies that is, policies comprising articulation of wide strategic agendas across sectoral policy domains, not just the traditional science-push policies centred around European or National R&D programmes, but including for example, all levels of education, training and lifelong learning, policies for the information society, health innovation, sustainability policies (including green innovation, renewable energy, etc.), SME policies and so on.

Top-level articulation of agendas is not however just an issue of ensuring coherence and policy collaboration across levels and across sectoral policy domains. Different degrees of decentralization for innovation-related matters or different degrees of devolved competences, often cause further institutional fragmentation across levels of government and across innovation policy domains, and justify the need for top-level policy supervision and coordination.

An interesting example of innovation policy coordination at the European level is the so-called RIS3 (Research and Innovation Smart-Specialization Strategies). The notion of smart specialization is related to development of capabilities at the regional level. According to Foray et al. (2009) European regions—in particular the less advanced and transition regions—need to build not only generic capabilities but also capabilities within specific fields, technologies and sub-systems in order to have competitive advantages in a few market niches. A smart specialization strategy is a policy process suggested by the EU to its member countries/regions and articulated at the EU level. At sub-national governance levels, the dynamics of discovery, experimentation and development of new local specialist fields should be facilitated by local governmental interventions.

4.4.2 *Innovation Policies at Sub-national Governance Levels*

While national governments and supra-national authorities may focus on wide strategic innovation agendas, sub-national levels and regions in particular have been increasingly active in promoting their own regional innovation policies (Cooke et al. 2011). The increasing importance of the regional stance for innovation policies is perhaps, not only a result of delegation and devolution of powers to the regional level, but also the result of a number of other important factors (OECD 2011), namely:

First, governments have come to recognize the greater importance of proximity policies in many areas of the innovation policy spectrum, for example social innovation, entrepreneurial innovation, technology transfer, among others.

Second, advancements in our understating of the dynamics of innovation and its relation to space scales, and in particular the use the RIS—Regional Innovation Systems concepts, led to the recognition of a wide diversity of innovation contexts at the regional level. Local production structures and clusters are related to historical and knowledge patterns (Asheim and Gerler 2005), and their evolution depends on regional institutional capacity, knowledge absorption and the degree of connectivity of regions, among other factors (Amin and Thrift 1994).

Finally, rising demand for policy accountability and monitoring of outcomes has also highlighted the importance of sub-national levels as well as the complex interdependencies between institutional levels and the need to clarify overlapping responsibilities.

Therefore, there are today more opportunities for regional innovation policies enabling regions to participate in the multi-level innovation policy-mix (Nauwelaers and Winthes 2003). Within the multi-level innovation policy-mix, policies at sub-national levels may be designed to augment or complement top-level policies. For example, R&D funding obtained through the European Framework Programmes—and Horizon 2020, may be augmented/complemented by R&D activities at the regional level, funded by regional operational programmes under the European Structural Funds. Local actors already participating in transnational Horizon 2020 projects (already approved at the European level) could have administrative procedures for submission of proposals for complementary funding greatly facilitated. In addition local funding may complement R&D at the European level by focusing on market launch, local market testing or even in promoting local adoption and diffusion of innovations originated elsewhere.

While at the regional level policies may be designed to augment and/or supplement policies at upper levels, there is also room for regional specific policies that is, policies adapted to the local institutional context, tailored to the innovation capabilities profile and to the specific regional social-economic structure. These might include policies for quality and adaptability of the workforce; policies to attract and retain talent; to repositioning of local production and services in global value chains; entrepreneurship; local public procurement for new products and services; and policies for opening the regional innovation system and development of global connections.

For example, regions with a high proportion of firms with low innovation capabilities may need specific policies for accelerating the development of a well-educated labour force and in particular actions for building or attracting international technology institutes. For regions that passed beyond a threshold level of human capital, the focus may perhaps be on creating networks and linkages not only for consolidation and further development of the regional innovation system, but also linkages to extra-regional research and technology support infrastructure.

Depending on what specific institutional settings may already exist that is what agencies and institutes exist at sub-national governance levels, other areas of specific innovation policy that may benefit from proximity and therefore be more efficiently delivered al the local level, are the promotion of creative and cultural industries, cluster policies and delivery of innovation support consultancy services. At sub-national levels it may also make sense to have specific R&D policies designed to attract talent, for example by having special programmes to attract the best international researchers. Another area of innovation policy that clearly benefits from proximity is technology transfer, both outside-in and local in the sense that at the regional level there may be specificities related to how the region insources technology and knowledge from other regions and how it transfers to local actors.

Despite, numerous opportunities for the local/regional level to participate in the multi-level innovation policy-mix, there are also potential problems. First, there are conflicting arguments as to whether the regional level is adequate to develop policies for promoting systemic innovation. At least from some regions insufficient institutional thickness (Amin and Thrift 1994) may be a major barrier. Second, the regional mix must avoid falling into a too localized a view of innovation. Whereas some regional actors may be connected to the regional innovation system, others may need better connectivity outside the region rather than linkages to the regional innovation system. In other words, because universities and/or research infrastructure with relevant research for the region may be located in other regions, policies for research-to-industry collaboration at the regional level need to balance intra- and extra-regional scopes (Cooke 2001; Howells 2002).

4.5 Final Discussion

The complex process by which innovation policies are designed, transferred or transformed into effective policy-making instruments remains poorly understood. By and large, most research on innovation policies focus on single policies, without consideration about how they interact and produce combined effects.

In this chapter we proposed to characterize innovation policy making in three different dimensions: issues associated to multi-rationales that is the reasons and justifications behind public intervention, which condition the design and implementation; multi-actors that is issues related to how different innovation policies should be formatted to target different actors as well as targeted to systemic aspects of the innovation process; and multi-level governance that is issues associated to how different policies at different levels and scopes could or should be articulated.

In our view policy rationales based on concepts and evidences may play an important role, perhaps not because of their merits, stricto sensu, but perhaps because policy makers may use them as ex-post justifications to legitimize policy decisions already taken. Although the neoclassic rational of market failure compensation appears to be dominant, alternative approaches such as innovation system or the triple and quadruple helix are visible in policy discourse. Overall, in practice, policy rationales co-exist and policy makers may simultaneously make explicit or implicit use of different types of rationales (conceptual, evidence-based, ideas) to justify their mix of innovation policies.

It may also help to see innovation policy as a mix of policies, and their associated policy instruments, targeted at actors with different roles or functions in the innovation system. In addition, in the domains of innovation where business firms play a major role, we propose that innovation policy-mixes should consider to segment firms by innovation capabilities. Firms with lower innovation capabilities will most certainly need different kinds of support, when compared to firms with higher levels of innovation capabilities. And to complement the multi-actor innovation policy-mix the innovation system as a whole could also be considered as a target. Perhaps there has not been enough concern with balancing the innovation policy-mix with policies oriented towards systemic aspects of innovation alongside policies oriented towards types of actors.

Finally, our proposal considers a mix of innovation policies at different governance levels that is multi-level policies. In our view, different types of innovation policies are more efficiently delivered at different governance levels. European or National level innovation policies, within the multi-level mix, may perhaps be more efficient if focused in coordination and articulation of lower-level policy strategies and actions. Therefore they focus on broad policy agendas crossing not just governance levels but also different policy domains. On the other hand, lower-level governance levels are perhaps more efficient if designed to complement or augment higher-level policies, while at the same time, even if replicating policies in other political stances, aiming at specific local issues, more efficiently tackled through proximity policies based on local specific relations.

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CHAPTER 5

The Fourth Helix in Smart Specialization Strategies: The Gap Between Discourse and Practice

Carlos Rodrigues and Filipe Teles

5.1 Introduction

The development of regional innovation networks has been an increasingly important phenomenon since the 1990s (Geddes 2010, p. 204; Powell and Grodal 2006, p. 57), being even one of the current central guidelines of European Union (EU) regional policies (Collinge and Gibney 2010, p. 379). Unlike the previous top-down, national-oriented and standardized innovation policies, this new paradigm of innovation policies is mostly based on the promotion of regional competitiveness factors (OECD 2007, pp. 31–35). Therefore, there has been a particular focus on the development of integrated approaches in which there is a clear attention to the relational dimension (Collinge and Gibney 2010, p. 379). Moreover, the complexity of contemporary policy implementation has shifted governing models from hierarchical and fragmented structures to more collaborative and flexible systems. Policy coordination between institutions, as well as the

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identification of the correct mix of instruments, has become official tenets of today's regional governance discourse. It is under this context that Asheim and Gertler (2006, p. 3000) mention the concept of "regional networked innovation systems", which are characterized by the existence of policies which foster and plan the relational and learning processes among regional actors.

The recent focus on smart specialization as conceptual ground for EU innovation policy design elevates this relational dimension from an instrumental stance—underpinning the interactive learning processes essential to materialize innovation policy, up to a cornerstone for the design of innovation policy itself. As such, one can argue that the relational dimension becomes central in the rationale for smart specialization, namely concerning the participatory process through which, on the one hand, what is unique in the economic fabric of a given region is defined, and, on the other hand, the research and development (R&D) innovation domains the region can hope to excel are revealed (Foray et al. 2009). The participatory process, in the conceptual framework of smart specialization, is equated to an entrepreneurial process of discovery (Foray 2009; McCann and Ortega-Argilés 2013; OECD 2013) and assumes the status of a provider of policy innovation, by distinguishing smart specialization from traditional industrial and innovation policies (OECD 2013). The "distinctive, original, and modern" areas of specialization (Foray and van Ark 2007, p. 3) are expected to stem out from this entrepreneurial process of discovery.

Despite the academic and political discourses regarding smart specialization strategies and the entrepreneurial ecosystems, particularly underlining the additional role of society ("knowledge society") referred by the Quadruple Helix Innovation Systems Conceptual Framework, literature is more fragile in assessing the dilemmas it poses. Although innovation is regarded as an essential tool in European policy for the 2014–2020 period and considered as instrumental for the promotion of economic growth and employment, this cannot be considered with disregard to the specific territorial resources, governance and institutional capacity of each region.

This chapter seeks to address these gaps in literature. Empirically, it presents an in-depth case study of a particular regional setting (the Region of Aveiro in Portugal) and the process that led to the definition of its Territorial Development Strategy for the 2014–2020 period. Within this backdrop, this chapter also strives to shed light on the current debate on regional governance.

5.2 Networked Systems of Innovation and Smart Specialization

The synthetic definition of the system of innovation provided by Lundvall (1992, p. 2), according to which "[...] *a system of innovation is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge*", by highlighting the interactive nature of innovation, brings about a major stylized insight: innovation capacity is highly dependent on the ability to develop and consolidate networks upon which a wide array of actors cooperate to generate, disseminate and utilize relevant knowledge. Lundvall's definition can also be associated to the acknowledgement that the knowledge bases bearing innovation are made of different types of knowledge, generally contrasted by their codified or tacit nature. The basic idea, as put by Pavitt (2002) is that productive knowledge cannot be fully codified, as it contains tacit elements that can be learned only by emulation and practice. These tacit elements are hardly codifiable, as well as transmittable over long distances. As such, they are embedded in the social and institutional contexts in which they are produced (Gertler 2003), or, similarly, they are spatially sticky. Asheim and Gertler (2006, p. 295) provide an insightful overall picture: "*the process of knowledge generation and exploitation requires a dynamic interplay between, and transformation of, tacit and codified forms of knowledge as well as a strong interaction of people within organizations and between them*".

This set of intertwined arguments on the innovation process are combined in the conceptualization of regionally based systems of innovation, defined by Cooke et al. (1998, p. 1581) as systems in which "*firms and other organisations are systematically engaged in interactive learning through an institutional milieu characterised by embeddedness*". As such, a regional system of innovation can be regarded as an institutional infrastructure supporting innovation in a spatially bounded economic structure (Asheim and Gertler 2006). Different types of regional innovation systems can occur, as Asheim and Isaksen (2002) suggest. They distinguish between three main types of systems: *territorially embedded regional innovation networks*, in which innovation is mostly based on localized learning processes stimulated by geographical, social and cultural proximity, lacking significant interactions with knowledge-generating centres; *regional networked innovation systems*, which, though also based on localized interactive learning dynamics, embrace a wider array of regional institutions active in the innovation process, emphasizing its planned nature, that is, the role played by the policy realm in its strengthening; *regionalized national innovation systems*, characterized by an increased integration of the regional productive and institutional settings in national or international innovation systems.

Networked systems approximate ideal and typical territorialized innovation systems (Asheim and Isaksen 2002). In addition, this typology, more encompassing in institutional and organizational terms, calls forth a relational dimension (Collinge and Gibney 2010) that endorses the consideration of a governance perspective on the dialectical linkage established between innovation and space (Crescenzi and Rodríguez-Pose 2011). Cooke and Morgan (1998) discuss this governance dimension of innovation systems with basis on three models. First, the *dirigiste* model, in which innovation activities are thrust mainly from outside the region (the centralized decision-making process that gave rise to the spreading of technopoles in France is a paradigmatic example). This model equates a regionalized national system of innovation (Asheim and Isaksen 2002). Second, the *grassroots* model, based on the occurrence of a soft infrastructure of innovation support that emerges from the efforts of local, grassroots organization aimed at coping with the absence of central dirigisme (e.g. the *kohsetsushi* system of small- and medium-sized enterprises [SME] technology centres run by municipalities and prefectures in Japan, as well as the local SME support schemes evolving in some industrial districts in Italy). The grassroots model is similar to what Asheim and Isaksen (2002) call territorially embedded regional innovation networks. Third, the *network* model, presenting high levels of coordination among multi-level policy structures as well as simultaneously complementary and competing actors (the German state of Baden-Württemberg is often regarded as approaching the network model). In Asheim and Gertler (2006) this model becomes one of a regionally networked innovation system.

Regionally networked innovation systems can be regarded as mirroring the complex realm of contemporary development policy design and implementation, which conveys a shift from hierarchical and fragmented governing structures to more collaborative, thus interactive, and flexible systems. Policy coordination among a variegated set of institution and decision levels, together with the identification of a correct mix of instruments, emerge as tenets of the predominant thought on innovation-driven regional development policy (Flanagan et al. 2011; Borrás and Edquist 2013).

The current focus on smart specialization as conceptual ground for EU regional policy design extends the relational dimension inherent to networked systems of innovation from the instrumental level that ignites the interactive learning processes nourishing innovative activity to the core of the design of innovation policy itself. In fact, the concept of smart specialization is built up on the assumption that the economic success of a given region depends on its capacity to identify, on the one hand, what is unique in the regional economic fabric, and, on the other hand, the R&D innovation domains the region can hope to excel (Foray et al. 2009). This capacity, in turn, is fuelled by a participatory process, which, using the words of McCann and Ortega-Argilés (2013, p. 10), takes the form of "*a partnership-based policy process of discovery and learning on the part of both policy-makers and entrepreneurs*". The literature on the subject calls it an "entrepreneurial process of discovery" (Foray et al. 2009, 2011; OECD 2013).

5.3 The Entrepreneurial Process of Discovery and the Quadruple Helix Innovation Systems Conceptual Framework

As suggested before, the smart specialization concept has been swiftly translated into the policy realm, emerging as a "new innovation policy", as in the official definition provided by the European Commission: "*smart specialisation is a new innovation policy concept designed to promote the efficient and effective use of public investment in research*". According to the official discourse, the policy aim is one of achieving economic growth and prosperity. The way to achieve is to boost regional innovation by enabling regions to focus on their strengths in order to avoid the dispersion of investment across a variety of technological areas, which, arguably, would hamper the impact in any one of those areas.

Accordingly, smart specialization strategies rely on a so-called entrepreneurial process of discovery, which is expected, using the words of Foray et al. (2009, p. 1), to "reveal what a country or region does best in terms of science and technology". The same authors equate this to a learning process directed at discovering the research, development and innovation domains in which "a region can hope to excel" (ibid.). The rationale is that through this learning process regional stakeholders, as in Foray et al. (2009, p. 2), "*are likely to play leading roles in discovering promising areas of future specialisation, not least because the needed adaptations to local skills, materials, environmental conditions, and market access conditions are unlikely to* *be able to draw on codified, publicly shared knowledge, and instead will entail gathering localized information and the formation of social capital assets*".

The entrepreneurial process of discovery is commonly deemed as the driver which confers to smart specialization a distinctive character *vis a vis* previous rounds of regional innovation policy, characterized by a top-down approach in which decision making was attached to regional authorities, with no or little participation of relevant stakeholders. Policy design, in the framework of this top-down *modus operandi*, is seen by the smart specialization proponents as being naïve, due to the exclusion of "*knowledge essential for success—entrepreneurial knowledge*" (Foray and Goenaga 2013, p. 5), and the major cause for unsuccessful regional innovation policies. Therefore, the solution lies on mobilizing entrepreneurs—taken in the broadest sense—to participate in a learning process capable of generating the (entrepreneurial) knowledge needed to discover the specific "*distinctive, original, and modern*" areas of specialization (Foray and van Ark 2007, p. 3) in which a given region can excel. The public sector, as suggested by Foray et al. (2009), assumes the status of a facilitator and catalyst of the entrepreneurial process of discovery. Top-down policies are admitted, though restricted in focus to "*grand challenges*", or, in other words, broad societal and systemic needs (Foray 2009, p. 71): "*The definition of a grand challenge has to be made at a very macroscopic leve—i.e. the objectives or challenges are 'large-grained'—while the microscopic choices regarding the kind of 'fine-grained' goods (technologies and innovation) to be developed should be left for markets to determine*".

In this context, one can argue that the smart specialization process approximates the Mode 3 knowledge production system (Carayannis and Campbell 2012, p. 3), as it is meant to energize "*bottom-up civil society and grassroots movements initiatives and priorities to interact and engage with each other toward a more intelligent, effective, and efficient synthesis*" combined with top-down public policy approaches to the so-called grand challenges.

It is in this context that the Triple Helix (TH) of university-industry-government relationships (Etzkowitz and Leydesdorff 1997) is viewed as insufficient to deal with the challenges of smart specialization. Following Foray et al. (2012, p. 22), the "*perhaps most common, tripartite governance model based on the involvement of industry, education and research institutions, and government (the so-called Triple Helix model), is no longer enough in the context of smart specialisation*". Though acknowledging the TH as an important ingredient in building up regional innovation capabilities in the framework of smart specialization (e.g. Goddard et al. 2013), the argument is that it does not match the requisites of the Mode 3 knowledge production systems referred to above. In other words, the model, in its original formulation, does not accommodate the need for taking on board the design of smart specialization strategies "*innovation users or groups representing demand-side perspectives and consumers, relevant non-profit organisations representing citizens and workers*" (Foray et al. 2012, p. 22).

Accordingly, an additional helix is added to the tripartite arrangement of university-industry-government, the one representing what Yawson (2009) calls the public. The resulting Quadruple Helix Innovation Systems Conceptual Framework, in the vein of Carayannis and Rakhmatullin (2014, p. 218), because emphasizing cooperation—in the form of co-opetition, co-evolution and co-specialization—within and across innovation ecosystems "*could serve as the foundation for diverse smart specialisation strategies*", as well as to "*introduce a move towards systemic and user-centric innovation structures*". Martinez and Palazuelos-Martinez (2014) add the claim that all relevant regional stakeholders should be involved in the dynamics of this quadruple helix and alert for the imperative of a swift from traditional governance modes to a process of "collaborative leadership". Foray et al. (2012) look at this collaborative leadership as a crucial element to prevent the capture of the entrepreneurial process of discovery by specific interest groups, on the one hand, and to ensure flexible decision-making processes allowing for each actor to play a role and even take the lead in specific phases of smart specialization design, "*according to actors' characteristics, background, and capacities*" (ibid., p. 22).

In this framework, it seems crystal clear that the qualities of collaborative leadership, that is, the success of any smart specialization strategy, are highly dependent on the robustness of institutional and governance structures (Morgan 2016). In other words, the geographies of context, as Gertler (2003) would put it, cannot play second fiddle in the debate on the challenges inherent to the endeavour to energize, organize and consolidate quadruple-helix dynamics feeding the design of smart specialization strategies.

5.4 The Case of the Region of Aveiro: A Smart Specialization Strategy for 2020?

This section focuses on the horizontal dimension of the partnership principle in collaborative arrangements, as it refers to the participation of regional stakeholders in public policies processes. It deals with a joint policy design instrument framed as the preparation of an Integrated Territorial Development Plan, necessary for the implementation of the 2014–2020 Regional Strategy. As such, it discusses the problem of the fourth helix in a specific "geography of context".

The case of the region of Aveiro was chosen for two main reasons. First, it allows us to test the impact of structural funds as a trigger of stakeholders' cooperation and the extent to which it enables the internalization of the co-production principle of public policies. Second, in this particular Region, this process involved not only a specific inter-municipal entity, representing all local authorities, but it also entailed a protocol with other regional stakeholders—namely an Industry Association and the University of Aveiro. As such, we are dealing with a cooperative arrangement with a mixed character, which has—in principle—the engagement of regional stakeholders. As it has been recognized, Europe 2020 Strategy strongly recommended the need to extend the possibilities for the active involvement of sub-national stakeholders and of all levels of governance not only to ensure the democratic legitimacy of the Europe 2020 strategy (Frazer et al. 2010, p. 41), but also to promote horizontal and bottom-up forms of learning by incorporating a wider set of perspectives and information sources (Zeitlin 2010). This emphasis is due to the perception that one of the failures of the Lisbon Strategy is related to a limited participation of non-state and sub-national actors, who were generally confined to formal consultation and/or information exercises, with limited opportunity to influence substantive policy direction or content (Zeitlin 2010).

5.4.1 Brief Picture of the Economic Context

The Region of Aveiro includes 11 municipalities with 370,000 inhabitants. It is characterized by a relevant industrial activity, with several national leading companies, with significant export activity. Besides the Region of Aveiro, only the districts of Lisbon and Porto have higher performance regarding their relative weight in GDP and exports. In this national picture, the metallurgical, chemical, food, automobile, non-metallic minerals and electrical equipment sectors account for over 60 % of industrial activity in the region.

According to a recent report from the Regional Industry Association, the agents of the abovementioned sectors identified workers' skills and technological innovation as the most common factors to explain the competitiveness and internationalization of the region. The same study shows that about 55 % of companies undertake innovative activities and technological development, underlining also their cooperation with the University of Aveiro.

The economic differentiation factors of the Region result both from the existing industrial dynamism, with the transformation and evolution of traditional sectors with greater integration of technology and innovation, and from its relationship with the scientific and technological system. One should also add the geographical factors, which enable mobility and accessibility, besides the existence of relevant institutional resources in the territory.

In the early 1970s of the last century, its regional economy was mostly based on the primary and secondary sectors, both labour intensive. Agriculture, animal farming, forestry, fisheries, marine salt and clay extraction were the most relevant activities in the primary sector. These natural resources stimulated the development of flourishing industries such as agro-food, fish processing, wine production, wood industry, pulp-and-paper, cork, and ceramics, among others. Also, a chemical industry pole was established in the surroundings of Aveiro lagoon, focused on the production of primary chemicals and, later, on petrochemical derivatives.

Two major national initiatives, launched in the 1970s, strongly influenced this Region's economy in the following years: the establishment of the Innovation Center of Portugal Telecom in the city of Aveiro, and the foundation of the University of Aveiro. The first aimed at surveying the last technological developments in the European telecommunications sector and developing new knowledge and technologies for the Portuguese telecommunications infrastructure and services. The second was the result of a national policy aiming at the expansion of the higher education system in Portugal, with new universities especially focused on regional needs.

The University of Aveiro (UA) was created in 1973 started its activity precisely within the building and facilities of the Innovation Centre of Portugal Telecom. This fact has been determinant in the definition of the University's mission: an innovative university, focused on science and technology, strongly oriented to promote innovation, boosting the economic and social development of the Region and of the country. The initial academic training and research activities were indeed on the domains of electronics and telecommunications, ceramics and materials, environment and marine sciences and technologies, natural and agro-food products, as well as fundamental sciences. The University's degrees were designed mostly to meet industry demands, particularly for the established clusters or emerging industrial domains in the region. A special attention has also been given to job training, involving industrial partners. This young university was also able to attract many young and highly skilled national and international professors and researchers, which strongly contributed to the creation of excelling research units and to its international profiling. In parallel, in the last few decades, it has created a number of interface units mostly oriented to support entrepreneurship and business creation, innovation and technology transfer as well as professional training.

The flourishing economic and industrial activity claiming for new knowledge and innovation, the establishment of an innovation centre for telecommunications, the creation of an innovative university strongly committed with Regional development, can be considered as the main ingredients for the seeding of an innovative and entrepreneurial ecosystem in the Region, firstly focused on Information and Communication Technologies (ICT) and, later, on other national and relevant economic clusters.

ICT is one of the economic areas that mostly benefited from the university-business partnership. This long-term cooperation involving joint pioneering education and research activities, promoted the creation of a strong regional ICT cluster, involving about 60 companies (SMEs, most of them), with an annual turnover of around 370 M€. This dynamics has attracted to the Region several national and international companies, and the headquarters of the ICT National Cluster.

Forestry is, also, one of the consolidated clusters in the Region. The biggest national pulp-and-paper producer has updated its local infrastructure, improved its production capacity and has established the "Forest and Paper R&D Centre" in the region. The University of Aveiro is also one of the stakeholders of this centre. Cork industry has evolved from a mono-product industry to high-tech cork products, including high performance insulating materials. The Technology and R&D Centre of cork industry sector is also located in the Region. In the Agro-food sector, after a period of crisis, induced by the decline of traditional activities, new technology and precision agriculture is creating new market opportunities. Also, the wine sector has evolved to a modern, knowledge intensive activity.

As far as fisheries and sea economy is concerned, although the fishing fleet has almost disappeared due to international competition and to the EU policy for the sector, the fish processing sector is growing, with new technologies and products. Also, new aquaculture initiatives (fish, shellfish and algae production and transformation) are now running or being installed in the region. However, the potential of the sea and Aveiro lagoon resources is far from being explored. New opportunities, like in the blue biotech sector, are emerging, bringing new challenges for the Region and their stakeholders.

The ceramics sector has suffered a big shift from traditional products to high performance materials for building applications. The headquarters of the National Cluster for the Habitat Sector have been established at the University of Aveiro. The energy sector has also observed a tremendous development over the last 40 years: the Region has attracted multinational companies, and the world Bosch Centre of Competences for Thermotechnology, is installed in Aveiro.

5.4.2 The Entrepreneurial Ecosystem Within a Regional Strategy

In the last few years, the instruments to support the innovation and entrepreneurial ecosystem have gained a new impetus with the implementation and/or development of a set of individual or joint initiatives, supported by the long-term cooperation between the university, enterprises and the local and regional government bodies. The University of Aveiro has launched a strong entrepreneurship programme inside academia, covering the whole "entrepreneurship pipeline", from education and training to supporting business creation and acceleration, involving the different university departments and schools, the technology transfer office and the university-business incubator.

Nowadays, the financial income resulting from such activities represents about 10 % of the university's annual budget. This result is a direct consequence of (i) the European, national and regional funding programmes, promoting business innovation, and of the (ii) university policy, stimulating the university-business cooperation, strengthening the supporting interface units, and creating new interaction approaches, such as Technology Platforms, involving researchers and infrastructures from different research centres, aiming to tackle economy needs, using an holistic and multidisciplinary approach.

As an example of the activities developed within the scope of the university-region strategic cooperation programme, a single multipolar incubator, with poles in different municipalities was launched in the last few years as an instrument to promote local entrepreneurship and social innovation, involving the University of Aveiro and the Inter-Municipal Community (Council of Mayors) of the Region of Aveiro, with the collaboration of the Industrial Association. The university entrepreneurship training activities initially directed to academia, are now open to the whole Region, and its incubation programme and services (including mentoring, access to funding, among others) are shared with the surrounding municipalities, supporting local entrepreneurship policies.

The local entrepreneurship programmes have been accompanied by municipal and regional industrial development policies aiming to attract new companies to the Region, giving them conditions to grow and compete in global markets. Within this context, several new generation municipal or inter-municipal industrial parks were built (or are being planned) in the region, attracting new investments.

This has led to the recognition of this Region as one of the most innovative in Portugal, encompassing all the ingredients of an entrepreneurial ecosystem: a highly reputed university developing research and innovation activities and preparing highly qualified human resources; a strategic partnership between the university, the industry stakeholders and the local and regional authorities; and infrastructures, including a university technology transfer office and technological centres, university and regional business incubator, providing support to business development and innovation, industrial parks with easy terrestrial and maritime accesses.

Within this context, the Inter-municipal Community and the University of Aveiro established a long-term partnership, namely by defining and implementing an integrated and joint strategical plan for the economic, social and cultural development of the Region, creating joint initiatives aiming to promote entrepreneurship as well as the competitiveness and internationalization of the regional economy.

This commitment towards territorial development policies, especially through the reinforcement of local authorities' interactions with the University of Aveiro, had, already in 2008, one of its seeds. In that year's Territorial Development Plan, the Triple Helix Innovation Systems Conceptual Framework was considered in that strategy as its core and new mechanisms of inter-municipal and inter-institutional cooperation in the region were underlined as significant, particularly through the development of common projects.

This process became even more evident with the Integrated Territorial Development Strategy for the new period (2014–2020), developed between 2012 and 2014. In this case, again as a result of a robust interaction with the University and other regional stakeholders, there has been a clear identification of innovation and entrepreneurship promotion as the main regional policy challenges. The role of public authorities in assuring the success of this TH based regional development approach is particularly clear in the process of developing a common strategy between regional authorities, the university and the private sector, allegedly based on smart specialization principles. This is also true in its contents: programmes and actions to be implemented in order to promote development, growth, social inclusion and employment through reinforcing and strengthening the regional innovation ecosystem.

This new regional development strategy considered as its smart specialization areas, jointly proposed by the Council of Mayors and the University of Aveiro: “Sea and the Aveiro Lagoon”, “Information and Communication Technologies”, “Materials” and “Agro-Food and Forest”. Having common priority areas in the regional Integrated Territorial Development Plan is a clear evidence of the fact that this instrument emerged from a pre-existing context where collaboration, specialization areas, industry development, knowledge transfer and research were naturally going hand-in-hand.

However, this evidence is mostly a result of close working and common strategy development between three major agents in the region, rather than a comprehensive articulation of numerous stakeholders. In other words, the fourth helix, namely as seen by Yawson (2009), did play a pale role in the overall process. In order to explain this claim, the next section looks at the process that led to the definition of the Integrated Territorial Development Strategy for 2014–2020.

5.4.3 The Steps for the Definition of the Regional Development Strategy

With the conclusion of the 2007–2013 programming period, the European Commission has enforced a new mechanism for a more efficient allocation of structural funds between regions. This process, previously associated with the development of regional innovation strategies, was now dependent on a smart specialization regional strategy. This was seen as a mechanism to facilitate the articulation of European financing instruments with regional needs, in order to maximize their economic potential for growth and innovation. At the heart of these strategies was the identification of the skills and regional strengths to support innovation, and the sectors and clusters with the capacity to support economic growth and employment. The thoughtful selection of public policy priorities should have ensured diversification and recognition of the systemic nature of innovation. The inter-municipal, national and European coordination should have been also relevant concerns in this process.

Smart specialization also assumes the creation of a collective and shared strategy by several regional stakeholders, with the identification of competitive and comparative advantages resulting from the innovation potential of the territory in question, which would allow for a co-created definition of priorities in the use of smart policies to maximize development, growth and innovation. It was desirable that in these processes, and where possible, the universities would play an important role in this definition.

As clearly stated in the preliminary documents that led to the definition of the region of Aveiro's Integrated Territorial Development Strategy, and in fact in its final version, these were the principles that were being claimed as central to the process that would rely on an entrepreneurial process of discovery. This—so claimed—distinctive character of smart specialization strategies would lead to a significant number of impacts in regional economy and would result in changes in public policy incentives and local and regional governance. This required institutional changes, multi-level and inter-sectoral coordination of public policies, the promotion of cooperation and co-governance mechanisms.

The process under analysis in this chapter was the result of a two years' intensive work between the Inter-municipal Community of Aveiro and the University of Aveiro. A team of researchers and of members designated by the Council of Mayors was put together to design and conduct the whole process to deliver the regional strategy. This was consubstantiated in a protocol between the two institutions, which assumed the general principles previously mentioned. It had the following methodological approach, in three stages: (a) survey and characterization of the Region, (b) alignment and prioritization of policies and (c) the definition of an action plan and monitoring mechanisms.

Stage 1: Survey and Characterization

For the survey phase and characterization of the Region of Aveiro the following instruments were identified as necessary:

- *Regional Characterization*: The smart specialization strategies need to be anchored not only in skills available in terms of regional economy and its innovation structures, but also the prospects for future development. It adopted a comprehensive view of innovation that goes beyond the traditional boundaries of business activity and technology, and involved all sectors of society. This characterization resulted therefore in the analysis of (1) regional strengths, (2) its position in the European and global economy, and its potential for internationalization, and (3) the business and entrepreneurial environment.
  This characterization implied the involvement and participation of regional stakeholders from various sectors of activity (academia, entrepreneurship, health, education, social economy, public administration).
- *Challenges to Public Policies*, particularly those resulting from multilevel coordination (EU, National and Regional): it was important to ensure the alignment and coordination with the new framework of the Common Strategic Framework and Cohesion Policy for 2014–2020, providing the means for a better perspective on how preferences and local priorities are articulated with the new regional and national strategies under the partnership agreements, the European challenges and territorial management tools.
- *Assessment of previous regional instruments and implementation*: The previous experience of the Inter-municipal Community of Aveiro and the process of elaboration and implementation of their Territorial Development Plan 2008–2013 was a source of relevant knowledge and information.
- *Innovation potential*: For the definition of a strategy for growth and innovation it was important to ensure the identification, coordination and prioritization of specific territorialized economic sectors associated with the different interactions between the areas related to smart specialization strategies: territory, public policies and knowledge. Thus, each of these interactions was considered in order to allow a more careful and shared identification between stakeholders of existing regional assets and future regional challenges. Like the Regional Characterization, this tool led to the involvement and participation of regional stakeholders from various sectors of activity.

Stage 2: Alignment and Prioritization

- *Governance*: The fact that smart specialization strategies and their implementation result from the articulation of the various agents of cross-sectoral and multi-level origins, required the development of a specific strategy for governance and monitoring of their implementation during the 2014–2020 period. This was dependent on the proposed definition and establishment of a governance model for the Integrated Territorial Investments that would follow the Integrated Territorial Development Strategy.
- *Vision*: As a result of the four instruments of stage 1 (Characterization, Challenges, Assessment, Innovation prospective) it was possible to identify a comprehensive scenario that formed the basis for the development of a vision for the region in 2020, with the identification of its main objectives and its relative importance.
- *Priorities*: This phase was necessarily developed at the municipal level (in each of the 11 municipalities of the Region), since it was important to consider the repercussions of inter-municipal and inter-institutional strategic guidelines to the local priorities and municipal existing strategies. Nevertheless, this also included the identification of public investment priorities of inter-municipal and inter-sectoral nature.

Stage 3: Action Plan Definition

- *Action Plan*: The set of public policy incentives and the necessary action plan resulted from the process of enhancing the detail of the technical and political aspects of the priorities identified at the end of the previous phase. The objective was the qualification of decision making, validating them at the inter-municipal level and establishing the necessary and possible links between the regional and municipal level, with the identification of common and specific policy areas, their planning, budgeting and financing source.

5.4.4 *Main Actors or Main Stakeholders: A Small Relevant Difference*

The European context emerges as a critical trigger of the involvement of Higher Education Institutions (HEI) in regional development, by redefining the procedures related to the decision making and management of European Structural Funds. Besides imposing a specific policy framework on the member states managing authorities that distribute the Structural Funds, EU regulations and policy documents forced local authorities to follow new procedures and to meet new standards in a set of policy areas, which require new expertise and problem-solving capacity. As a result, the development of cooperative linkages between local governments and knowledge institutional spheres has been encouraged (Winters 2009).

This is not particularly new, since the European financial framework for 2007–2013 had also put an emphasis not only on actor and territorial networks, but had also encouraged inter-institutional partnerships (Santinha et al. 2009; Zerbinati 2012), resulting in a potential increase in cooperation strategies (Teles and Kettunen 2016). Thus, it has been argued that it has induced an important shift in patterns of governance, as it stimulates a transfer from traditionally centralized decision-making processes—where each institution would be solely focused on their particularly restrained fields of activities—to a more open process. At the same time, the institutionalization of these new procedures, as well as long-term partnerships and HEI involvement require new learning processes. In fact, they entail a change in the perspective of local government actors regarding the role of HEI. Their likelihood to cooperate to promote economic development is substantially increased if local authorities perceive that transaction costs are low (Feiock et al. 2009). These transaction costs include problems associated with information asymmetries; to the difficulties of local authorities in reaching an agreement over cooperative efforts and the division of gains; and to the costs associated with monitoring cooperative agreements (Feiock et al. 2009; Hawkins 2010). If these costs are overcome—potentially through trust and reciprocity that can frequently emerge from repeated interaction and a history of informal relationships (Hawkins 2010, p. 256)—local authorities can engage in strategic partnerships with neighbour local authorities and other regional stakeholders, which allow municipalities to combine and coordinate resources and amenities, thus promoting greater effectiveness—more services and better delivery at a lower cost (Kersting and Vetter 2003).

This process, within the Region of Aveiro, had some routines of interaction already established given the experience of preparing the previous Territorial Development Plan. However, in the situation under analysis, the main challenge, besides improving and expanding this interaction, was to "enlarge the network" and engage with a significant and diverse number of other regional stakeholders, with a multi-sector approach to deal with the region's development goals. The preparation of this strategy meant the creation of a partnership, with specific governance architecture highly dependent on the already established network of two main agents: the Inter-municipal Community and the University of Aveiro.

Though this is definitely a core interaction within the entrepreneurial process of discovery, vital to the literature on smart specialization strategies, all the others were lacking, both horizontally and internally. In the first case, relevant stakeholders were expected to be involved, in a process that needed to go beyond the usual consultancy to specific groups of regional actors, and move towards a more systemic innovation structure. In what should be the dynamics of a quadruple helix, with a necessary turn from the traditional approaches to governance, this process required a more flexible, bottom-up and collaborative mode of governance. Evidently, it relied mostly on a top-down call for engagement of stakeholders, with no particularly relevant change in the traditional methods of participation. Though an important expansion of the scope and role of the main institutions involved was observed, this can only be seen as a transition towards a more complex co-production system of public policies, since it lacked most of the characteristics literature tends to claim that a Quadruple Helix Innovation Systems Conceptual Framework should encompass.

Nevertheless, in the case of internal changes to the institutional settings of both the University and the Inter-municipal Community, there was an evident effort to develop intra-organizational tools to engage them in this process. The innovative character of this partnership—since it represents a significant departure from a confined perspective of academic-industry relationship based on consultation only and a limited approach to academic-government interactions based on knowledge and power exchanges, was focused on the wider scope for entrepreneurship and innovation co-production of public policies. This meant that at the start of the partnership a great deal of effort and energy had to be invested in setting of rules of interaction and creating trust among the actors. This was particularly relevant given local governments' difficulty in sharing the leadership of this process with an institution not traditionally associated to regional development.

The commitment of local authorities and of the university regarding the timely preparation of the new strategy for the 2014–2020 funds, revealed the willingness to accept the partnership principle, as an integral part of the local approach to regional development policy. Although potentially limited in their reach, both the previous experiences of interaction and these new commitments were significant steps, particularly in a country with hardly any experience of collaborative policy making. This created opportunities to foster informal links and networks, generally perceived not only as a useful mechanism for the dissemination of knowledge, but also as an instrument to establish a bridge among the technical staff of local governments. This process, particularly since it took two years to implement, was also useful to overcome the emerging difficulties related to the co-definition of an agenda.

5.5 Challenging Inter-municipal Cooperation

An essential element that increases the complexity of governance mechanisms derives from the scarcity of inter-municipal cooperation strategies. As its Southern European counterparts, the Portuguese context presents features that tend to point to a limited capacity of regional actors to engage in collaborative initiatives. Moreover, there is an absence of a strong tradition of inter-institutional cooperation, which was furthered by a pattern of competition between municipalities and a lack of cooperative policy-making traditions. This dilemma is further complicated because different municipalities have their own capacities, financial settings and different (partisan) preferences. The fragmentation and high number of cleavages between (potentially) competing interests contribute to competition between municipalities. Naturally, these considerations further complicate decision-making processes.

Several strategies were put in motion to tackle these dilemmas. The first is related to a common discourse among mayors, who assume that they were dealing with incentive structures that play a prominent role in inducing local governments' cooperative arrangements. The EU funding process was the main underlying force that induced local governance partnerships and inter-institutional cooperation. In parallel, the reduction of national funds, particularly in a context of deep economic and financial crisis impelled local governments to develop additional efforts to obtain consensus.

Besides the discourse on financial incentives, it is also suggested that tackling the difficulties in the decision-making processes emerging from the lack of inter-municipal cooperative traditions required not only the intensification of leadership practices, but also an increase in the efforts concerning the dissemination of information. Both roles were largely attributed to the Inter-municipal Community, which regularly collected information on the development of projects. Also, carrying decisions forward was achieved through complex processes of consultation and negotiation among municipal actors. Deadlocks in decision making were often circumvented by the (frequently recognized) informal influence and leadership of the Inter-municipal Community and the mediating role of the University, often seen as an impartial player in this process, suggesting the need to equate the importance of political leadership willingness to take responsibilities in the governance process (Teles 2014). Such a role was also relevant to achieve some degree of convergence of perceptions.

"Soft" strategies to induce cooperation were also relevant in the creation of new mechanisms of accountability. Partners involved in the preparation and implementation of the Integrated Territorial Development Strategy were accountable to their partners, linked by informal control mechanisms and mutual trust (Teles 2016). This form of accountability based either on trust or the informal influence and leadership of an "external" actor had potential disciplining effects.

5.6 Challenging the Cooperation with Other Regional Stakeholders

The shift towards new modes of governance implies that municipalities have to take powers of other actors into account when designing local strategies and policies. Several scholars have questioned the extent to which governance mechanisms should involve agencies that are not directly subject to democratic controls. Local governments are, indeed, better placed to mobilize support from citizens. The possible drawback is that what is locally popular may not be what is strategically optimal. Also, local governments may be less prepared to take into account the spill-over effects of their decisions on other territories. Hence, as Klijn and Koppenjan (2000) put it, "because it is the task of governmental organizations to uphold and further the common interest, they should, rather than refraining from network games, actively seek to organize and manage them".

Engaging with other regional stakeholders is not an easy task, though. Local governments had to deal with the difficulties emerging from this integration, as it furthered the diversity of interests, perceptions and available resources. This was perceptible particularly regarding the inclusion of a HEI as a partner in the decision-making process. Previous routines of interaction were framed under "policy programmes" that revolved around precise goals within one single policy area and dealt with the management of local or regional resources, without a multi-sectoral approach to deal with the region's development problems.

Municipalities faced an important dilemma. As it has been theoretically suggested and empirically demonstrated, political elites tend to react negatively to the increasing bureaucratized control of politics. However, as Papadopoulos (2007) posits, it acquires a new dimension in network governance where bureaucrats can tightly cooperate with external experts. Politicians, on the contrary, are mandate holders, constrained by electoral pledges and have to anticipate electoral sanctions. They fear being bypassed by the bureaucracy and academic expertise involved. This is particularly relevant in our case study. The fragmentation in the nature of actors involved was feared; particularly a significant number of mayors were recently elected and were not engaged in the previous process of preparation of a territorial development strategy.

Nonetheless, a perception of deep changes emerged when the usefulness and appropriateness of the partnership approach is observed. Mayors assumed a pragmatic advantage, in the sense that the partnership with other municipalities and other regional stakeholders allowed local governments to understand the new way of thinking in terms of the EU regional funding strategy.

Overall, then, despite the identified pattern of scarce inter-municipal cooperation strategies, which present an unfavourable environment for the development of horizontal partnerships, the dynamics established during the process of applying for EU Structural Funds, unveil an increase in voluntary inter-municipal collaboration. Hence, it can be generally assumed that even in countries with an unfavourable environment for partnership, the EU funding process can boost institutional capacity and trigger local governance partnerships. Also pointing to an internalization of the partnership principle and specifically, to the role of HEI in regional development is the fact that both mayors and academics assumed their desire to improve policy practices and its outcomes through the inclusion of academic knowledge.

5.7 From Policy Rhetoric to Territorial Embeddedness

As we have tried to demonstrate, the region of Aveiro had already the necessary conditions to promote increasingly comprehensive policies, programmes and tools in order to foster innovation and entrepreneurship, as a path to territorial development. It was in this context that the actual Integrated Territorial Development Strategy took shape, as a platform for the promotion and coordination of regional resources and stakeholders, contributing to the consolidation and enrichment of existing networks among a wide range of institutions, public or private in nature.

This does not mean that this has been a simple and straightforward process. The necessary alignment between agents and the identification of the specialization areas is not just a matter of characterization and diagnosis. It requires, most of all, will, commitment and evidence. The needed regional agreement and interaction between several agents is a long, slow and important process. The complex process that led to this important step, and the learning capital resulting from this collaborative arrangement, give some assurance regarding its role in fostering an institutional learning and cooperative environment. Nevertheless, it relies mostly on the capacity and leadership skills of those individuals heading each institution (Teles 2015), rather than a culturally embedded practice of collaboration, co-production of knowledge and co-production of public policies.

This step towards a new platform for effective collaboration was intended to play an important role in the facilitation of cooperative solutions between the regional stakeholders to strengthen the competitiveness of the territory. However, the process that led to the preparation of this strategy was expected to work as an open platform for innovation and knowledge exchange, which would represent a challenge for all agents involved, both in terms of governance model, inter-institutional dialogue, and collaborative attitudes, as well as in the quality of the results obtained. Regarding the set of conditions presented as necessary to foster a quadruple-helix mode of institutional relationships, there were significant signs in our case study to consider the entrepreneurial process of discovery as to somewhat extent distant to the literature claims.

The gap between academic and political discourse on the fourth helix and Smart Specialization Strategies is particularly evident, since, on the one hand, even the TH approach is seen as fragile and highly dependent on leadership and coordination, and, on the other hand, the step towards a

Mode 3 of knowledge production systems would require taking on board a set of stakeholders usually absent (naturally or forced to) of these processes.

We believe that the concept of Smart Specialization Strategies does not need new approaches. Neither do we intend to question its core literature, nor the policy activities being conducted under its label. However, in this context, we suggest a more careful and in-depth analysis of the conditions for the entrepreneurial process of discovery, and of the institutional settings required to achieve such conceptual ground for territorial innovation and development. The relational argument is central to the concept, and collaborative arrangements require further inquiry on the special role institutions and individual play in the mobilization of the quadruple-helix agents, and how they work as facilitators of interactions, specially focused on promoting new knowledge, new businesses, new technologies, and, ultimately territorial development.

The way the Region of Aveiro managed an innovative and complex network, unveils the capacity of complex partnerships to have long-term spill-over effects. However, different stakeholders could have coped with the constraints and European imposed policy-rules without changing their core features. Therefore, adopting the Quadruple Helix Innovation Systems Conceptual Framework can prove itself as more of an exercise of rhetoric discourse, still far from the needed institutional maturity and collaborative practices present in the territory. More than a changing concept, this takes into consideration a new attitude, where the inclusion of multiple agents is an essential tool, and the shared commitment of all the territorial stakeholders a pre-requisite. Thus, more than an academic appraisal of the merits of the quadruple innovation helix nexus, there is a need to improve knowledge on the territorial resources, governance and institutional capacity of each region.

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CHAPTER 6

Supporting Knowledge and Policy-Based Stakeholders in Delivering Regional Impact: A Tool to Select Regional Scoreboard Indicators

Valerie Brett, Bill O' Gorman, and Óscar Afonso

6.1 Introduction

Regional stakeholders may have a tendency to concentrate on what they would like to achieve for their region as opposed to addressing their efforts towards the most prevalent needs of the region (Cooke 2001; Asheim and Gertler 2005). This paper outlines a tool that enables regional stakeholders to select which innovation indicators from the EU Innovation Scoreboard that if targeted, would deliver the greatest impact for the region. Regional stakeholders may have a specific remit which may limit their activities and

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impact to their own area of knowledge, expertise and skill sets (Cooke 2001; Asheim and Gertler 2005; Huang et al. 2012). Thus, there can be a predisposition and tendency to utilise current abilities, routines, systems, approaches and thinking when creating policy or practices to improve regional economies. The selection tool developed in this paper dictates to each region where there innovation focus should be in terms of implementing knowledge transfer practices and policies that drive innovation and competitive performance in context of the Technology Licensing (TL), Spin-Off Creation and Entrepreneurship and University-Industry Realtions themes.

The regional economy and the successful performance of national economies are often inter-related as national economic growth levels are often linked to regions and regional performance (Dogara et al. 2011). Regions are often far more open and flexible and potentially much more innovative than nations, which iterates the importance of regions to all stakeholders at both national and supra-national levels (McCann and Ortega-Argilés 2013). European regions have large cohorts of stakeholders and their is growing recognition of the Quadruple Helix (Carayannis and Campbell 2012) model which incorporates civil society as an innovation user and supports the concept of user-driven innovation policy (Arnkil et al. 2010). This extended Triple Helix Innovation Systems Conceptual Framework (Etzkowitz and Leydesdorff 2000) places innovation users at its centre as innovation is driven by its importance for the end user (i.e. civil society). Users and citizens own and drive innovative activities; they are users and appliers of knowledge and are thus relevant regional stakeholders with regional specific context and experiences.

Traditionally European policy focused on improving physical infrastructure which then progressed towards other popular policy approaches which strived to enhance regional economies through clustering and mimicking strategies and policies which identified and replicated characteristics of regional economic or industry sector success. However, this approach afforded little understanding of the growth path of regions (Asheim et al. 2011) and the knowledge and specialisms within the region. This led many regions to choose the same set of goals (Lagendijk 2011) or to focus their aims on the development of the same or similar industries. Foray et al. (2009) argued that regions should be distinctive and capitalise on what they do best. Furthermore, O'Gorman and Donnelly (2016) discussed the value of identifying regional specialisms and the importance of increasing the overall attractiveness of the region. The concept that regions should focus on what they do best has been embedded in recent European policy initiatives outlined in The Europe 2020 Strategy for Smart, Sustainable and Inclusive Growth (European Commission 2010). The Innovation Indicator selection tool illustrated in this paper supports all types of stakeholders within the quadruple helix as it provides a robust means of selecting where knowledge transfer policies and practices would have the greatest impact for a region and further bolsters regional smart specialisation design and implementation.

The following Section will discuss in more detail regional innovation systems and smart specialisation as a policy concept. This will be followed by an overview of the study and the regions selected; the innovation indicators and their relevance to the knowledge transfer themes. The methodology Section illustrates how Total Factor Productivity was applied to deliver the results for each region of the study. The results have been divided into a general analysis which presents the results for the five countries while a specific analysis presents the results for the 5 regions.

6.2 Regions and Regional Innovation Systems

There has been extensive progress within literature with regard to understanding regions and their potential which can be traced as far back as Marshall's (1890) new economic geography which focused on agglomeration economies, proximity (Krugman 1991, 1993, 1995), the competitive advantage of regions (Porter 1990, 1998), industrial districts (Becattini 1989; Harrison 1992) and the evolution of an economic population over time (Cooke 2002, 2001). The common context is the need to understand why some regions and countries perform stronger or are more successful than others. Regions develop and respond differently (McCann and Ortega-Argilés 2011) and this continued disparity between regions and regional economies is a key challenge across all spectrums of European policy and society. Contemporary thinking on the regional economy incorporates and identifies the ability of a region to learn (Morgan 2007; Hauser et al. 2007; Lundvall 2004; Asheim 1996; Lundvall and Johnson 1994) and drive innovation. Regional Innovation System (RIS) literature draws on many concepts already mentioned, however in the context of policy design and implementation all regions differ in their innovation capability and absorptive capacity; and one-size-fits all policy approach is ineffective (Tödtling and Trippl 2005). Smart specialisation as a policy approach adheres to the concept that regions must take into consideration their own regional nuances (O'Gorman and Donnelly 2016) when designing and implementing policy.

The Regional Innovation System (RIS) concept has been influential in the design of regional development policies and was in part derived from the former concept of the National Innovation System (Freeman 1987, 1995; Lundvall 1992; Nelson and Rosenberg 1993). Following Saviotti (1997), an innovation system can be defined as a set of actors and interactions that generate and adopt innovations. This definition recognises that innovations are not generated solely by individuals, organisations and institutions, but also by the complex patterns of interactions between those stakeholders.

The relevance of national innovation systems is related with the fact that the national dimension captures important aspects for the innovation process (namely, the policy and regulatory framework, educational and training framework, national economic and geographical environment). As referred by Cooke (2001), the evolution towards the RIS concept results from some convergence between the works of regional scientists, economic geographers and national systems of innovation. RIS relevance is based on the acknowledgement that proximity plays a major role in networks and interaction density which is attributed to the tacit nature of knowledge. Tacit knowledge "is best shared through face-to-face interactions, between partners who already share some basic commonalities: the same language, common "codes" of communication and shared conventions and norms" (Asheim and Gertler 2005, pp. 293). The regional dimension also generates a more focused knowledge basis, as a cumulative result of the clustering of economic and innovation oriented activities. Asheim and Gertler (2005) developed analogous arguments and stress that "the more knowledge-intensive the economic activity, the more geographically clustered it tends to be" (Asheim and Gertler 2005, pp. 291). Besides the cognitive and normative dimensions of RIS, that can present different degrees of intensity, the political dimension should not be excluded. Cooke (2001) referred to "region" as a key component of a RIS, considering it as a meso-level political unit set between the national or federal and local levels of government which may have some cultural or historical homogeneity and some statutory powers to intervene and support economic development, particularly innovation.

Difficulties associated with the RIS concept as an operational regional policy tool remain important. First of all, there is still some degree of vagueness of the concepts of innovation systems and of the limits established between national and regional systems (Uyarra 2010). Another set of difficulties arise by the fact that the RIS should be applied to quite different and specific regional contexts but, in fact, RIS concept is shaped for regions with strong technological endowments and with well-established institutional and organisational networks. Even within a strict knowledge-based economy perspective, regional differentiation is important because the knowledge base of the existing productive sectors is not the same and this affects the comparative relevance of actors and interactions.

Following the recommendations of the Knowledge for Growth group of experts, the EU has embraced smart specialisation as the theoretical frame for the design of innovation policies. The Barca Report (2009) highlighted the apparent inefficacy of EU comp.

The Barca Report (2009) highlighted the apparent inefficacy of EU competitiveness policies and presented, as one of the underlying reasons, the scattering of resources and the use of a general approach to target heterogeneous contexts, namely, regions (Foray and van Ark 2007; Sandu 2012).

Accepting the fact that regions cannot excel in all areas, smart specialisation emphasises the need for place-based policies that are tailored in function to each regions' specific assets and knowledge bases and the regions potential to build sustainable competitive advantages globally (Foray and van Ark 2007; Arancegui, Querejeta and Montero 2011; McCann and Argiles 2011). Following those conclusions, the concept of smart specialisation gained importance within the EU and became a reference and concept for a new approach to Cohesion Policy. However, the concept itself remains blurry (Arancegui et al. 2011; Sandu, 2012) and for once, the transfer into practice has surpassed the conceptual consolidation of the theory. Foray et al. (2011) stated that there existed a lag between policy practice and the theoretical framework of smart specialisation. Thus, it is important to present and discuss the concept and how smart specialisation can translate it into practice.

6.2.1 Smart Specialisation

The Smart Specialisation concept is derived from two strands of economic literature, one focused on the transatlantic productivity gap and the other on sectorial innovation systems (McCann and Argiles 2011). According to Foray and van Ark (2007) and Foray et al. (2009), smart specialisation is about the refocus of R&D and innovation in alignment with regional distinctive features. In other words, regions must specialise in order to be able to generate critical mass. However, Foray and Van Ark (2007) have always rejected the hypothesis of picking winners or over specialisation due to the obvious risks of technological lock-in and the risk of making a wrong choice. Authors like Pontiakis et al. (2009), Kyriakou (2009) and Giannitsis (2009) acknowledged that specialisation enables economies of scale but without diversity, thus related variety became a cornerstone of smart specialisation (or, as the McCann and Argiles (2011) name it "specialised diversification") policy. This has also been expressed by the European Commission which stresses the importance of diversification of related activities in order to reduce the risks of lock-in and of a shift in market demand (CEC 2010). Also Capello (2013) argued in favor of a "smart diversification and upgrading" and described smart specialisation as a way of matching knowledge and human capital, with the economic structure of regions and its potential to build competitive advantages (Camagni and Capello 2012). These authors also uphold the importance of embedding innovation policies in the local context as well as the importance of connectedness in order to ensure the maximization of knowledge flows internally. Innovation is a process of closeness and relatedness between people and this is why it is a mostly a localized process. The regional innovation system framework (Lundvall and Johnson 1994; Tödtling and Trippl 2005) demonstrated that regional innovation is based on local capabilities and cumulative learning processes, embedded in human and relationship capital. Therefore, knowledge diffusion is not a straightforward process but one that needs regionally-tailored policies.

Smart Specialisation policy strives to concentrate resources and to specialise regions in accordance to their potential. Although the polarisation argument makes sense, it also creates mechanisms for brain drain and economic crowding-out effects from lesser performing regions to frontier regions. Foray et al. (2009) argument is particularly illustrative as they argued that, smart specialisation should cluster in a few regions and subsequent regions should try to benefit from knowledge diffusion and invest in co-inventions, applied to the existing industry (David et al. 2012 and Sandu 2012). Lesser performing regions present structural shortcomings that need to be specifically targeted by public policy. In fact, besides the imbalance or lack of density in the regional innovation system, the poor external perception and the prevalence of market failures (e.g., venture capital) hinder a smooth transition of smart specialisation policy (Sandu 2012). Furthermore, some regions are overspecialised, which hampers their ability to create a variety of activities and hence build an appropriate ecosystem to co-invent. Consequently, a smart innovation policy must address the creation of preconditions for the consolidation of a regional innovation system for lesser performing regions, so that they can specialise in the future. Such policy must consider not only the present potential, but provide a framework to support emerging domains, reducing the risks of lock-in with diversification as one vector of the policy along with the re-composition of the economic and knowledge bases. Thus, we concentrate our work in operationalizing the concept of smart specialisation by proposing a tool which enables the appropriate selection of innovation indicators to support policy design and implementation.

6.3 The Regions of the Study

The EU Innovation Scoreboard is a tool that provides a comparative assessment of the innovation performance of European Member States. The aim of the scoreboard is to help countries and regions identify areas they need to address in order to improve their innovation performance. The scoreboard classifies European Countries and regions into the following groups; innovation leaders (regions that perform 20 % or more above the EU average), innovation followers (regions that perform above or close to the EU average), moderate innovators (regions performing between 50 and 90 % of the EU average) and modest innovators based (regions performing below 50 % of the EU average). The classification is based on each region's performance rating on a set of research and innovation indicators. The scoreboard provides guidance for countries and regions on their performance levels, therefore regional stakeholders can understand how their performance, in relation to certain indicators, alters over time and how their performance levels in comparison to other regions.

The formation of the research was based on five regions from within the EU and each region fell within one of the Innovation Scoreboard classifications (see Table 6.1); Innovation Leader (Germany; Sachsen Region), Innovation Follower (Ireland; Southern and Eastern Region), France (Centre-Est Region), Moderate Innovator (Portugal; Norte Region) and Modest Innovator (Romania; Bucharest-IIfov)[1].

6.4 Indicators and Themes

The research is based on the innovation indicators of the EU Scoreboard that are likely to be influenced by TL, SCE and UIR practices and policies. Therefore, it was important to identify which indicator belonged to which theme. As for the TL area, the indicators used are mainly linked to the

Table 6.1 Selected regions

Code	*Countries and Regions*	*2007*	*2009*	*2011*
DE	Germany	Leader	Leader	Leader
DED	Sachsen	Leader Low	Leader Low	Leader Low
IE	Ireland	Follower	Follower	Follower
IE02	Southern and Eastern	Follower Medium	Follower Medium	Follower High
FR	France	Follower	Follower	Follower
FR7	Centre-Est (FR)	Follower Low	Follower High	Follower Low
PT	Portugal	Moderate	Moderate	Moderate
PT11	Norte	Modest High	Moderate Low	Moderate High
RO	Romania	Modest	Modest	Modest
RO32	Bucaresti-IIfov	Moderate Medium	Moderate Medium	Moderate Medium

Source: Regional Innovation Scoreboard (2012)

number of patents applied for, R&D expenditures of government, higher education and business sectors. In the case of SCE the indicators used are related to employment in medium-high/high-tech manufacturing and knowledge-intensive services and manufacturing sectors, turnover of new or significantly improved products, trades and exports of high-technology products. The indicators used for UIR were linked to the tertiary education level, non-R&D innovation expenditures, SME's in-house innovation and co-operation activities, public–private co-publications and non-technological innovations introduced by SMEs. Table 6.2 provides a list of the innovation indicators that are more likely to positively impact the three themes selected (Table 6.2).

The selected indicators from the EU Innovation Scoreboard illustrate that in general, the most (less) innovative regions are in the most (less) innovative countries. However, there is also diversity between the five regions within each of the countries which highlights the importance of evaluating innovation performance at a regional level and not just at a national level. Each region within a country has different strengths and weaknesses therefore addressing that the innovation performance of a region can be more insightful in terms of understanding the overall potential economic performance. National and regional levels are key dimensions when it comes to the design and implementation of successful innovation policies. Thus, it is of the utmost importance to have indicators that allow for comparable performances and the monitoring of trends. Furthermore, while regional analysis is crucial, there is less data available at a regional level

Table 6.2 Indicators divided by knowledge transfer area

Indicators related to Licensing (TL) (A)	*Indicators related to Spin-offs (SCE) (B)*	*Indicators related to University-Industry (UIR) (C)*
1. Number of patents applied for at EPO, by year, into the Regional GDP in Purchasing Power Parity Euros; 2. Number of patents applied for at EPO, by year, per million of inhabitants; 3. R&D expenditures in the business sector (BERD), by year, into Regional GDP, in national currency and current prices; 4. Business Enterprise R&D expenditure (BERD) by economic activity—percentage of GDP; 5. R&D expenditures in the government sector and the higher education sector in Regional GDP; 6. R&D expenditures in the government sector and the higher education sector in GDP—percentage of GDP;	1. Number of employed persons in the knowledge-intensive services sectors and Number of employed persons in the medium-high and high-tech manufacturing sectors into total workforce; 2. High and medium to high-technology-manufacturing, % of total employment; 3. Knowledge-intensive services—Percentage of total employment; 4. Sum of total turnover of new or significantly improved products either new to the market or new to the firm for Small Manufacturing Enterprises (SMEs) by total turnover for SMEs; 5. Total high-tech trade in million euro—percentage of total exports;	1. Population with tertiary education per 100 population aged 25–64; 2. Total SMEs innovation expenditure, excluding intramural and extramural R&D expenditures, into the total turnover for SMEs; 3. SMEs introducing any new or significantly improved products or production processes (in-house innovations); 4. SMEs with innovation (co-operation activities in total number of SMEs); 5. Number of public–private co-authored research publications by total population; 6. Number of SMEs introducing new products or processes to market by total number of SMEs; 7. Number of SMEs introducing new marketing and/or organisational innovations to market by total number of SMEs;

Source: Innovation Scoreboard (2012) and Eurostat

than at a national level, therefore in some cases national indicators were considered. Eurostat and the Regional Innovation Scoreboard 2012 have been used as the main data sources for this study. Each of the 5 regions had to define their current status (Scenario 0) and the desired improvement they would like to achieve (Future Scenario). Each region's Scenario 0 was based on the level and growth rate of a set of innovation indicators that are likely to be influenced by TL, SCE and UIR. The future scenario was defined by bearing in mind the effect of the innovation indicators on the Total Factor

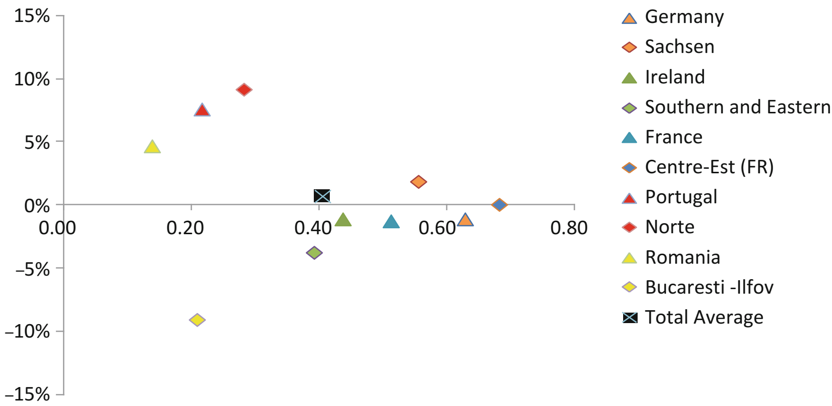


Fig. 6.1 European Patent Office (EPO), 2007–2011 (NI)—(Number of patents applied for at EPO, by year, into the Regional GDP in Purchasing Power Parity Euros) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

Productivity (TFP). Therefore, in general practices and policies that affect positively the EU Innovation indicators, which, in turn, are more connected with TFP (see Fig. 6.1) are what should be implemented within a region to improve its economic performance.

6.5 Methodology

In economics, TFP, A, also called multi-factor productivity, is a variable which accounts for effects in total output (GDP) not caused by traditionally measured inputs (physical capital, K; i.e., the machinery, and labour, L; i.e., the employees). TFP can be taken as a measure of an economy's long-term technological change or technological dynamism. An increase in either A, K or L will lead to an increase in output (economic growth), but while K and L inputs are tangible, TFP appears to be more intangible as it can range from technological knowledge to the knowledge of a worker (human capital). TFP is often seen as the real driver of growth within an economy and studies reveal that K and L are important contributors and TFP may account for up to 60 % of growth within economies. Thus, two competing countries/regions can have the same endowment of both machinery and workers; however, there will be different results created due to different

TFP. While the machines and workers are tangible factors, the organisation of machinery, creativity and human capital of a company are more intangible factors. In this research, the use of TFP is crucial to understand which variables, associated with the Knowledge/Technology Transfer, explain the evolution of the productivity in the different regions.

6.6 Findings

The results have been broken down and illustrated in the following format; section 6.6, (including 6.6.1, to 6.6.4) displays the indicators that are likely to influence each of the three knowledge transfer themes and then section 6.7 illustrates, in particular the results for each of the five regions in the study.

6.6.1 Indicators Likely to Be Influenced by Technology Licensing (TL)-Related Practices

This indicator (Fig. 6.1) represents the rate of new product innovation and thus the capacity of firms to develop new products, which determine their competitive advantage. Germany (Sachsen), France (Rhône-Alpes, Centre-Est) and Ireland (Southern and Eastern Region) are located above average, however better growth is observed in Portugal (Norte) and in Romania (Bucaresti-IIfov).

This indicator (Fig. 6.2) captures the formal creation of new knowledge within firms; it is particularly important in the science-based sector. Once again, Germany (Sachsen), France (Centre-Est) and Ireland (Southern and Eastern) are located above the average in level, but a higher growth rate is observed in Portugal (Norte).

R&D spending is essential for making the transition to a knowledge-based economy as well as for improving production technologies and stimulating growth; as such, this indicator (Fig. 6.3) provides key indications of the future competitiveness and wealth of the EU. Germany (Sachsen) and France (Centre-Est), as well as Bucaresti-Ilfov are located above average; however the growth rate is greater in Romania, in Portugal (Norte) and in Ireland (Southern and Eastern Region).

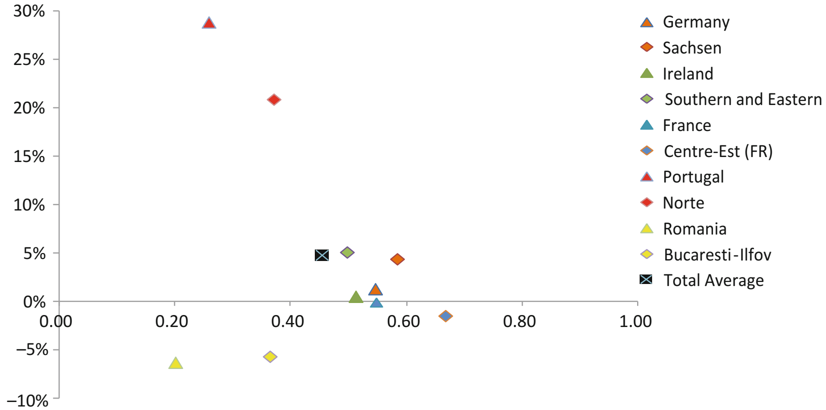


Fig. 6.2 Business Enterprise R&D expenditures in % of GDP, 2007–2011 (NI)—(R&D expenditures in the business sector (BERD), by year, into Regional GDP, in national currency and current prices) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

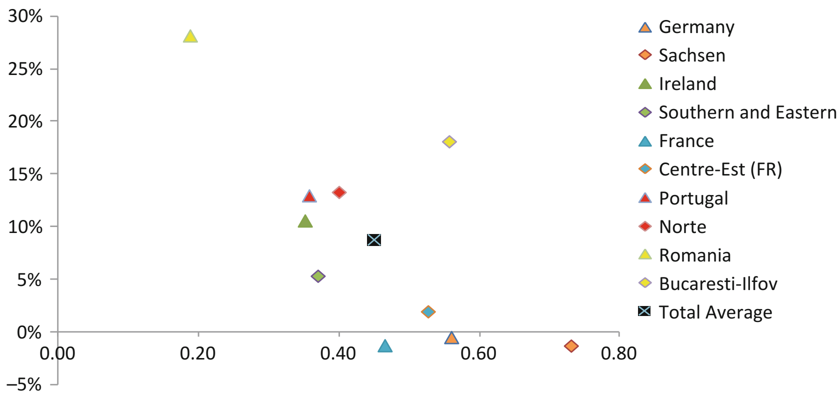


Fig. 6.3 Public R&D expenditures in % of GDP, 2007–2011 (NI)—(R&D expenditures in the government sector and the higher education sector in Regional GDP) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

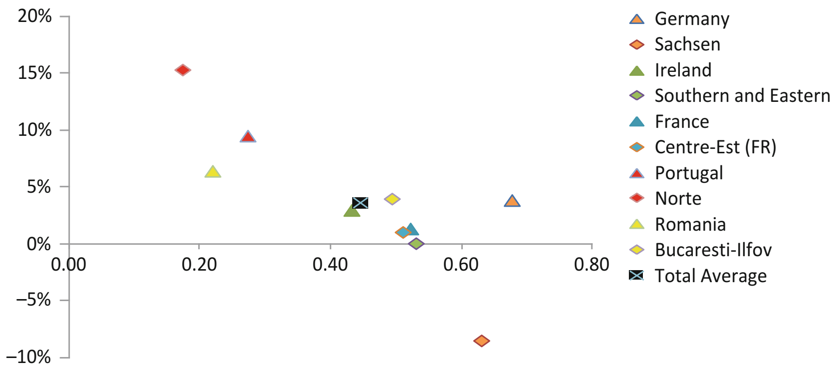


Fig. 6.4 Employment in medium-high/high-tech manufacturing & knowledge-intensive services, 2007–2011 (*NI*)—(Number of employed persons in the knowledge-intensive services sectors and Number of employed persons in the medium-high and high-tech manufacturing sectors into total workforce) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

6.6.2 Indicators Likely to Be Influenced by Spin-off Creation and Entrepreneurship (SCE)-Related Practices (Fig. 6.4)

Employment in knowledge-intensive services and in high-technology manufacturing sectors is an indicator of the economy that is based on frequent innovation through creative and inventive activity. Germany (Sachsen) and France (Centre-Est) are clearly located above average, but higher growth is observed in Portugal (Norte) (Fig. 6.5).

Germany (Sachsen) is located above average and in terms of growth rate, France (Centre-Est) presents the better performance.

6.6.3 Indicators Likely to Be Influenced by University-Industry Relations (UIR)-Related Practices (Fig. 6.6)

This is a general indicator of the supply of advanced skills; international comparisons of educational levels are difficult due to large discrepancies in educational systems, access and the level of attainment that is required to receive a tertiary degree. Ireland (Southern and Eastern) is located above average both in level and in growth rate; the growth rate is also strong in Portugal (Norte) and Romania.

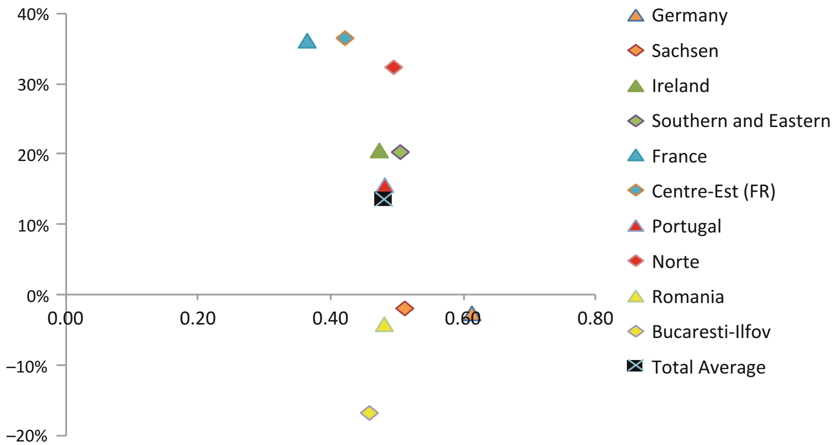


Fig. 6.5 Sales of new to market and new to firm innovations in % of turnover, 2007–2011 (NI)—(Sum of total turnover of new or significantly improved products either new to the market or new to the firm for Small Manufacturing Enterprises (SMEs) by total turnover for SMEs). (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

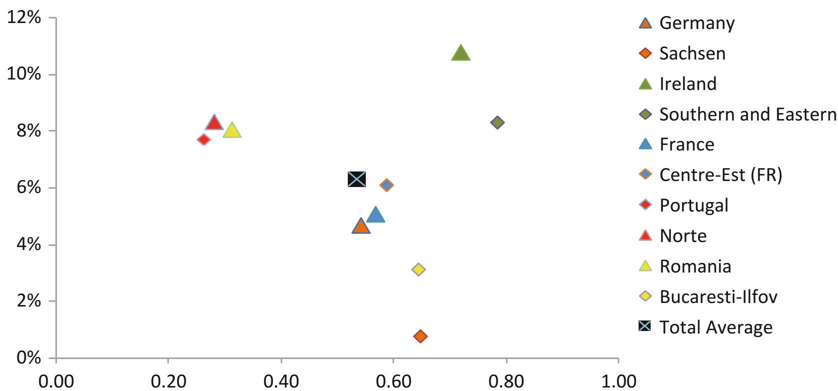


Fig. 6.6 Population with tertiary education per 100 population aged 25–64, 2007–2011 (NI) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

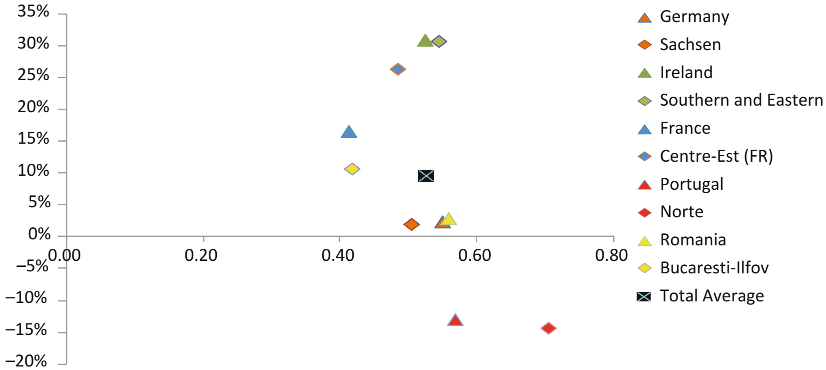


Fig. 6.7 Non-R&D innovation expenditures in % of total turnover, 2007–2011 (NI)—(Sum of total innovation expenditure just for SMEs, excluding intramural and extramural R&D expenditures, into the total turnover for SMEs) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

This indicator (Fig. 6.7) measures non-R&D innovation expenditure as % of total turnover; several of the components of innovation expenditure, such as investment in equipment and machinery and the acquisition of patents and licenses, measure the diffusion of new production technology and ideas. Ireland (Southern and Eastern) presents a good performance both in level and growth while the growth rate is poor in Portugal (Norte).

This (Fig. 6.8) indicator is limited to SMEs because almost all large firms innovate and because countries with an industrial structure weighted to larger firms would tend to do better. France presents a good performance in growth; Germany (Sachsen), Portugal (Norte) and Ireland (Southern and Eastern) are level.

This indicator measures the degree to which SMEs are involved in innovation co-operation; that is, the flow of knowledge between public research institutions and firms and between firms and other firms. Germany (Sachsen), France (Centre-Est) and Ireland (Southern and Eastern) are in a better position in terms of level; the growth rate is higher in Portugal (Norte) and in France (Centre-Est) (Fig. 6.9).

This indicator captures public–private research linkages and active collaboration activities between business sector researchers and public sector

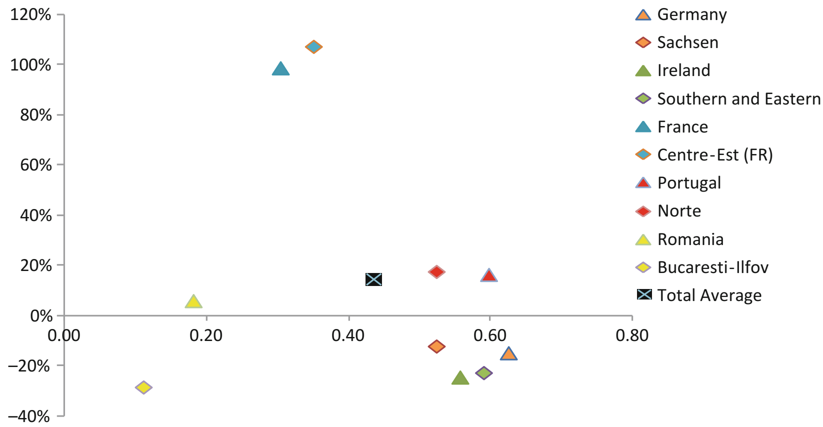


Fig. 6.8 SMEs innovating in-house in % of all SMEs, 2007–2011 (NI)—(This indicator measures the degree to which SMEs have innovated in-house, that have introduced any new or significantly improved products or production processes) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

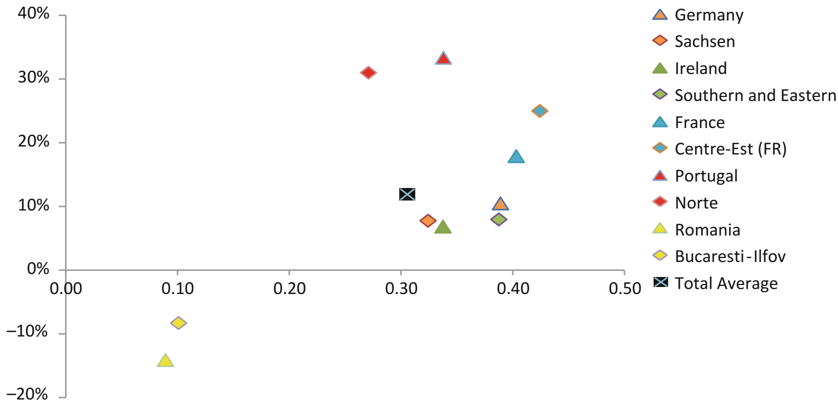


Fig. 6.9 Innovative SMEs collaborating with others in % of all SMEs, 2007–2011 (NI)—(SMEs with innovation co-operation activities [i.e., that had any co-operation agreements on innovation activities with other enterprises or institutions] in total number of SMEs) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

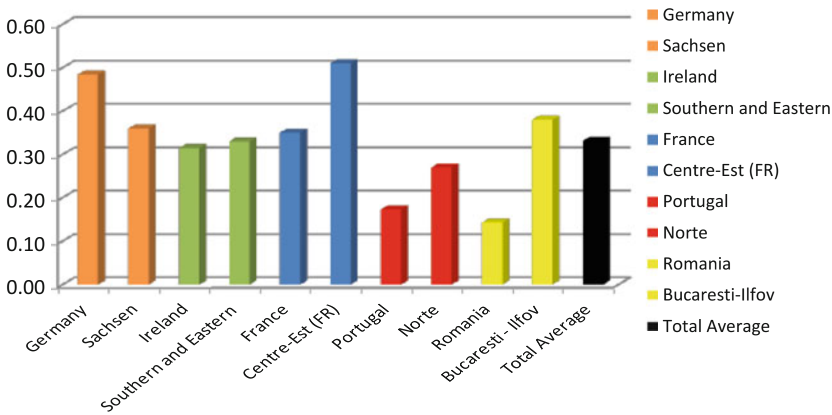


Fig. 6.10 Public–private co-publications, 2007–2008 (NI)—(Number of public–private co-authored research publications by total population)

researchers resulting in academic publications. Germany (Sachsen) and France (Centre-Est) are clearly located above average (Fig. 6.10).

Technological innovation as measured by the introduction of new products and processes is key to innovation in manufacturing activities; higher shares of technological innovators should reflect a higher level of innovation activities. Germany (Sachsen) and Portugal (Norte) are located above average in level, but higher growth is observed in France (Centre-Est) (Fig. 6.11).

This indicator tries to capture the extent that SMEs innovate through non-technological innovation. Germany (Sachsen) presents the best performance both in level and in growth rate (Fig. 6.12).

6.6.4 Normalised Composite Indicators by Knowledge Transfer Area and Global Composite

For this indicator (Fig. 6.13) the performance of Germany (Sachsen) and France (Centre-Est) is level and Portugal (Norte) shows (Fig. 6.13).

In this composite indicator, the performance of Germany (Sachsen) and Portugal (Norte) is level, while France (Centre-Est) and Ireland (Southern and Eastern) growth rate should be emphasised (Fig. 6.14).

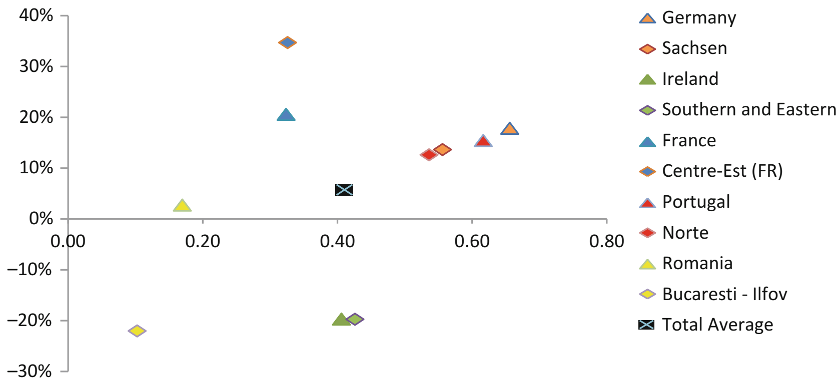


Fig. 6.11 Technological (product or process) innovators in % of all SMEs, 2007–2011 (NI)—(The number of SMEs who introduced a new product or a new process to one of their markets by total number of SMEs) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

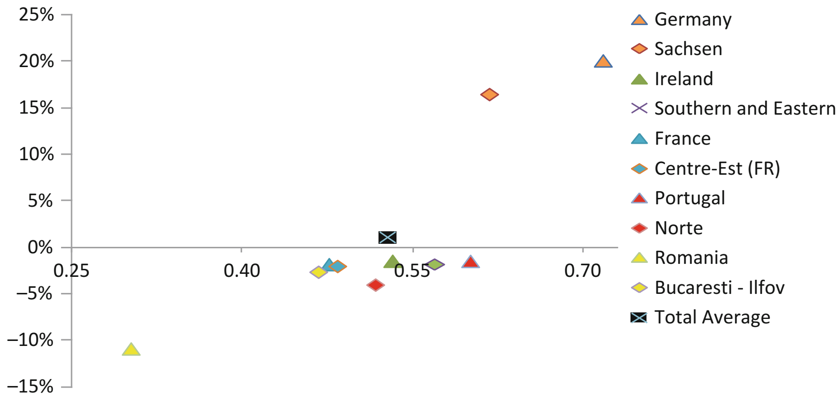


Fig. 6.12 Non-technological (marketing or organisational) innovators in % of all SMEs, 2007–2011 (NI)—(The number of SMEs who introduced a new marketing innovation and/or organisational innovation to one of their markets by total number of SMEs) (*Note*: *Y*-axis: average growth rate of the indicator between 2007–2009 and 2009–2011; *X*-axis: average level of the indicator)

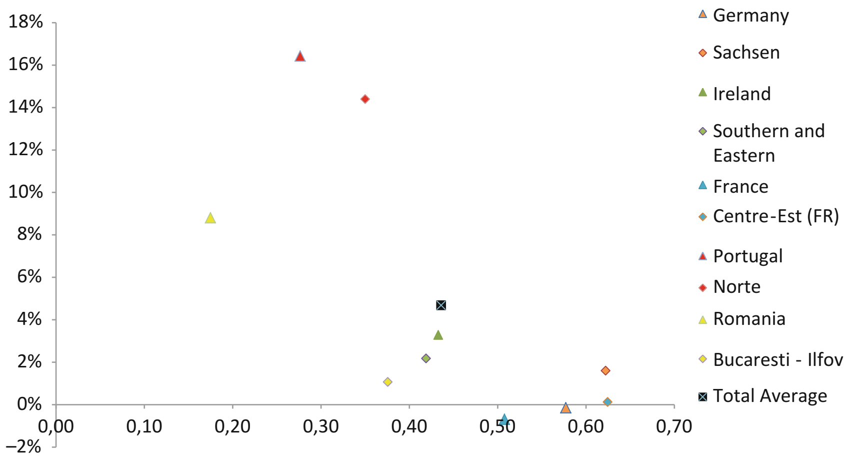


Fig. 6.13 Indicators influenced by technology licensing practices—composite indicator (*Note*: *Y-axis*: average growth rate of the indicator between 2007–2009 and 2009–2011; *X-axis*: average level of the indicator)

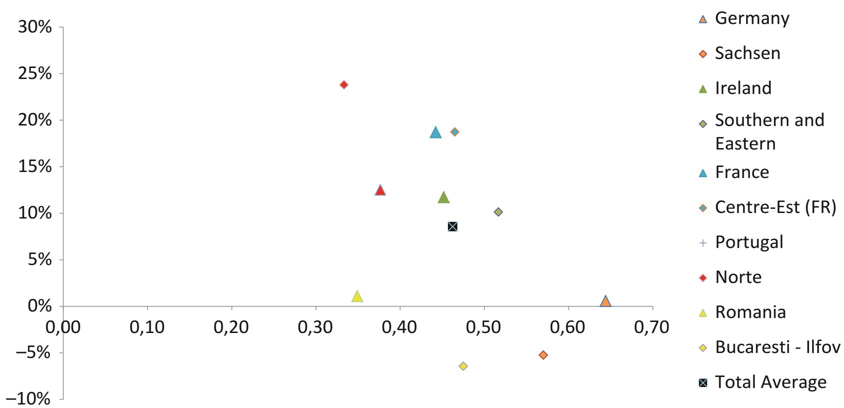


Fig. 6.14 Indicators influenced by spin-offs creation and entrepreneurship-related practices—composite indicator (*Note*: *Y-axis*: average growth rate of the indicator between 2007–2009 and 2009–2011; *X-axis*: average level of the indicator)

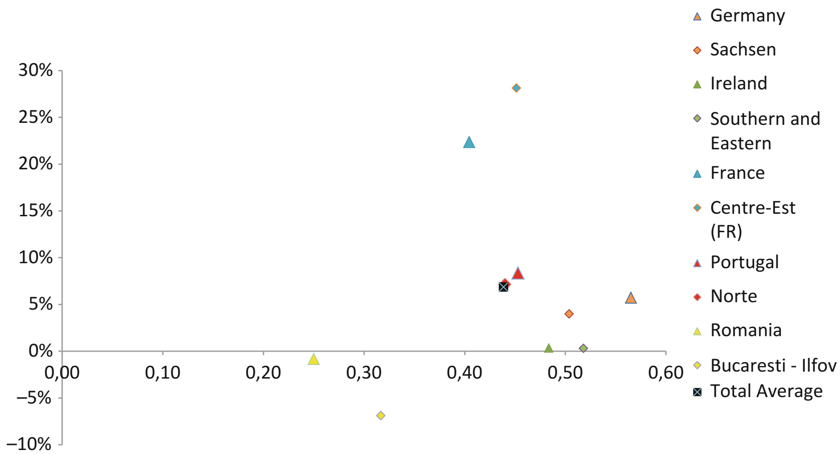


Fig. 6.15 Indicators influenced by university-industry-related practices—composite indicator (*Note*: *Y-axis*: average growth rate of the indicator between 2007–2009 and 2009–2011; *X-axis*: average level of the indicator)

For this composite indicator, the performance of Germany (Sachsen) and Ireland (Southern and Eastern) is level while the growth of France (Centre-Est) should be emphasised (Fig. 6.15).

Germany (Sachsen), France (Centre-Est) and Ireland (Southern and Eastern) present a good performance level in the global composite indicator. France (Centre-Est) and Portugal (Norte) have a good composite growth rate, while Portugal is in a process of catching up (Fig. 6.16).

From the analysis performed, the main conclusions are, in general: Germany (Sachsen) presents better performance in levels and France (Centre-Est) in growth rates. In France, an innovator follower, Centre-Est is an innovator (low) leader. Bucaresti-Ilfov, a moderate medium innovator, is much more innovative than other Romanian regions. To reach the position presented by Germany (Sachsen) and France (Centre-Est), the remaining regions need to have the capacity to incorporate knowledge spillovers similar to that in Germany and France. The capacity to learn, assimilate and implement advanced technologies can be particularly enhanced by: (i) domestic policies promoting R&D, (ii) the degree of openness and other trade policies and (iii) lower human-capital gap.

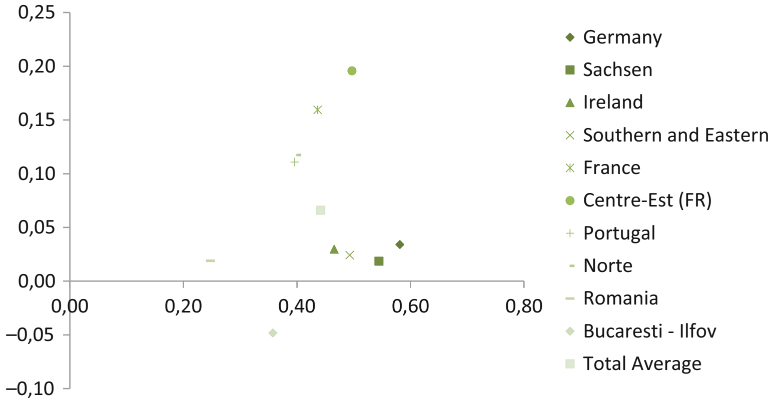


Fig. 6.16 Global composite indicator (*Note*: *Y-axis*: average growth rate of the indicator between 2007–2009 and 2009–2011; *X-axis*: average level of the indicator)

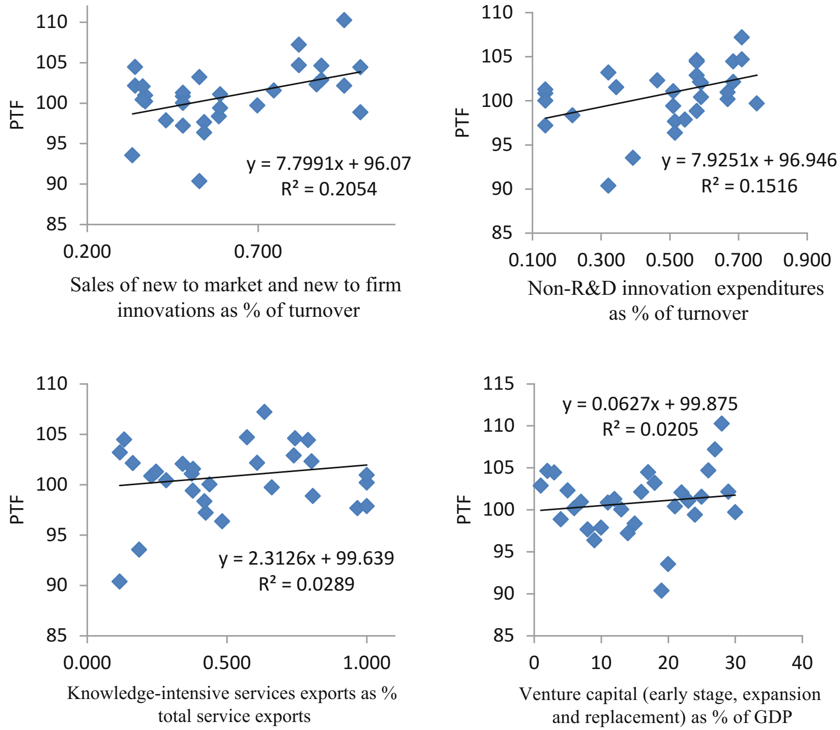
6.7 General and Specific Analysis

In this section the results are subdivided in a general analysis, and a specific analysis. The general analysis presents results for all five countries and the indicators used, while the specific analysis presents the results region by region.

6.7.1 *General Analysis*

The results have been obtained through econometric techniques in order to analyse the relationship between the indicator and TFP. In each case (Graph 6.1) every observation, represents the value of the TFP (*y*-axis) and the value of the indicator (*x*-axis); moreover, the line represents the adjustment, obtained through econometric techniques, between the TFP (*y*-axis, dependent or explained variable) and the respective indicator (*x*-axis, independent or explanatory variable). Starting with the general analysis, the most relevant results are the following:

In the case of the first figure (top left hand figure) the positive slope of the line indicates a positive relationship between the TFP and the indicator, which is also uncovered by the positive signal, which is variable *x*. Thus, the



Graph 6.1 Relationship between most relevant indicators and TFP (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

adjustment $y = 7,7991x + 96,07$ means that the value 96.07 of the TFP is explained by variables/indicators other than "Sales of new to market and new to firm innovations as % of turnover". The value 7, 7991 indicates that an increase by 1 in the indicator increases the TFP by 7, 7991. In turn, the R^2 statistic equal to 0, 2054 indicates that 20, 54 % of the variation of the dependent variable (TFP) is explained by the variation of the variable independent ("Sales of new to market and new to firm innovations as % of turnover").

In the total for the five regions, the results conclude that the most relevant indicators associated with the evolution of TFP are:

- Sales of new to market and new to firm innovations as % of turnover (Spin-off Indicator) rated 0.21;
- Non-R&D innovation expenditures as % of turnover (University-Industry Relations Indicator) rated 0.15;
- Knowledge-intensive services exports as % total service exports (Spin-off Indicator) rated 0.029;
- Venture capital (early stage, expansion and replacement) as % of GDP (University-Industry Relations Indicator) rated 0.021.

Thus, in general, the five regions should concentrate their efforts on the development of practices and policies that could influence these indicators by a descending order;

1. Sales of new to market and new to firm innovations as % of turnover has a relative importance of 51 %;
2. Non-R&D innovation expenditures as % of turnover has a relative importance of 37 %;
3. Knowledge-intensive services exports as % total service exports have a relative importance of 7 %;
4. Venture capital (early stage, expansion and replacement) as % of GDP has a relative importance of 5 %.

The following section of the results will illustrate the specific results of the countries involved in the sample which are Germany, France, Ireland, Portugal and Romania.

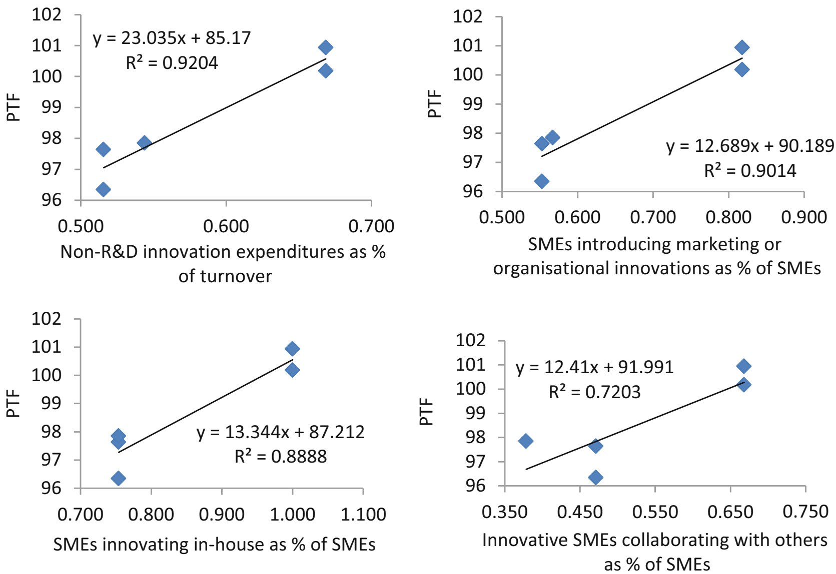
6.7.2 Specific Region Analysis

The most relevant indicators associated with the evolution of TFP for Ireland (Southern and Eastern) region are:

The first figure on the left for example, the positive slope of the line indicates a positive relationship between the TFP and the indicator, which is also uncovered by the positive signal which is variable x. Thus, the adjustment $y = 23.035x + 85.17$ means that the value 85.17 of the PTF is explained by variables/indicators other than “Non-R&D innovation expenditures as % of turnover”. The value 23.035 indicates that an increase by 1 in the indicator “Non-R&D innovation expenditures as % of turnover” increases the TFP by 23.035. The R^2 statistic equal to 0.9204 indicates that 92.04 % of the variation of the dependent variable (TFP) is explained by the variation of the variable independent ("Non-R&D innovation expenditures as % of turnover"), which is a strong relationship. To conclude the most relevant indicators associated to the evolution of TFP of Ireland (Southern and Eastern) are:

- Non-R&D innovation expenditures as % of turnover (U-I Relations Indicator) rated 0.92;
- SMEs introducing marketing or organisational innovations as % of SMEs (U-I Relations Indicator) rated 0.9;
- SMEs innovating in-house as % of SMEs (U-I Relations Indicator) rated 0.89;
- Innovative SMEs collaborating with others as % of SMEs (U-I Relations Indicator) rated 0.72.

In this sample, the UIR Indicator has great importance for the evolution of TFP. Ireland (Southern and Eastern Region) should concentrate on the development of practices and policies that could influence the indicators (as illustrated in Graph 6.2).



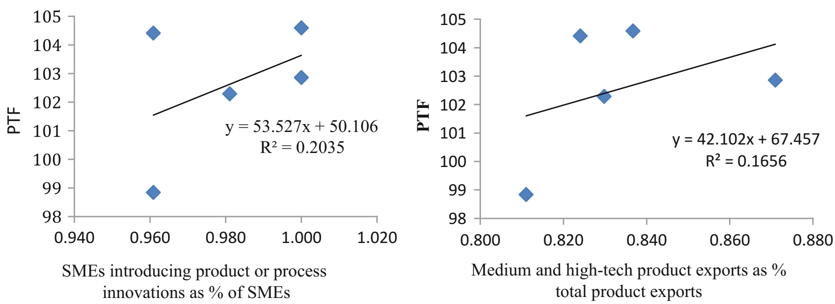
Graph 6.2 Ireland (Southern and Eastern Region) (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

The most relevant indicators associated to the evolution of TFP for Germany are:

- SMEs introducing product or process innovations as % of SMEs (University-Industry Relations Indicator) rated 0.20;
- Medium- and high-tech product exports as % total product exports (Spin-off Indicator) rated 0.17.

In this sample, the University-Industry Relations Indicator has a relative importance of 54 % and the Spin-Off and Entrepreneurship Indicator has a relative importance of 46 %. As a result, Germany should concentrate their efforts on the development of practices and policies that could influence the indicators (as illustrated in Graph 6.3).

In case of the first figure, for example the positive slope of the line indicates a positive relationship between the TFP and the indicator, which is also uncovered by the positive signal which is variable *x*. Thus, the adjustment $y = 23.035x + 85, 17$ means that the value 85.17 of the PTF is explained by variables/indicators other than "Non-R&D innovation expenditures as % of turnover". The value 23.035 indicates that an increase by 1 in the indicator "Non-R&D innovation expenditures as % of turnover" increases the TFP by 23.035. The R^2 statistic equal to 0.9204 indicates that 92.04 % of the variation of the dependent variable (TFP) is explained by the variation of the variable independent ("Non-R&D innovation expenditures as % of turnover"), which is a strong relationship. To



Graph 6.3 Germany (Sachsen) (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

conclude the most relevant indicators associated to the evolution of TFP of Ireland are:

- Non-R&D innovation expenditures as % of turnover (U-I Relations Indicator) rated 0.92;
- SMEs introducing marketing or organisational innovations as % of SMEs (U-I Relations Indicator) rated 0.9;
- SMEs innovating in-house as % of SMEs (U-I Relations Indicator) rated 0.89;
- Innovative SMEs collaborating with others as % of SMEs (U-I Relations Indicator) rated 0.72.

In this sample, the UIR Indicator has great importance for the evolution of TFP. Ireland (Southern and Eastern Region) should concentrate on the development of practices and policies that could influence the indicators (as illustrated in Graph 6.2).

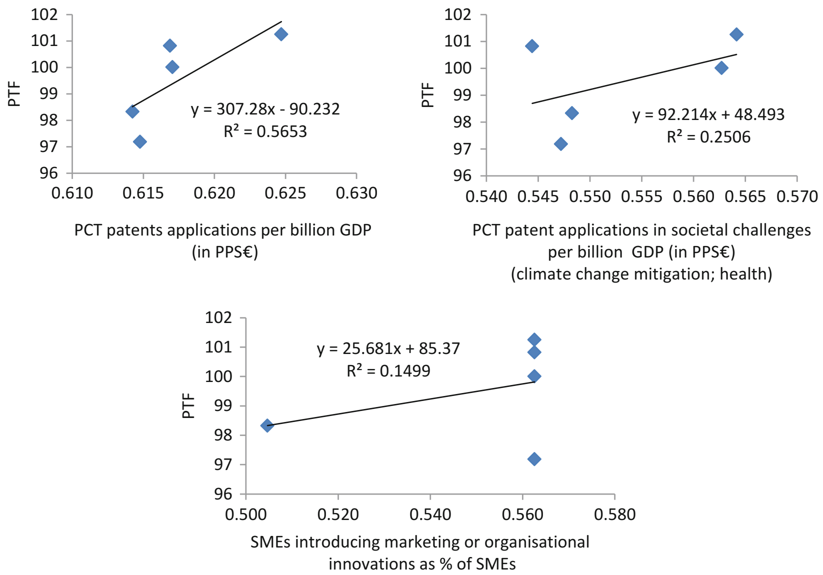
For France (Centre-Est) the most relevant indicators associated to the evolution of TFP are:

- PCT patents applications per billion GDP (Licencing Indicator) rated 0.57;
- PCT patent applications in societal challenges per billion GDP (Licencing Indicator) rated 0.25;
- SMEs introducing marketing or organisational innovations as % of SMEs (U-I Relations) rated 0.15.

In this sample the two TL indicators have a relative importance of 85 % and the UIR Indicator has a relative importance of 15 % in relation to the evolution of TFP. France should concentrate their efforts on the development of practices and policies that could influence these indicators (as illustrated in Graph 6.4).

The most relevant indicators associated with the evolution of TFP for Portugal are:

- Medium- and high-tech product exports as % total product exports (Spin-off Indicator) rated 0.36;
- Innovative SMEs collaborating with others as % of SMEs (U-I Relations Indicator) rated 0.17;



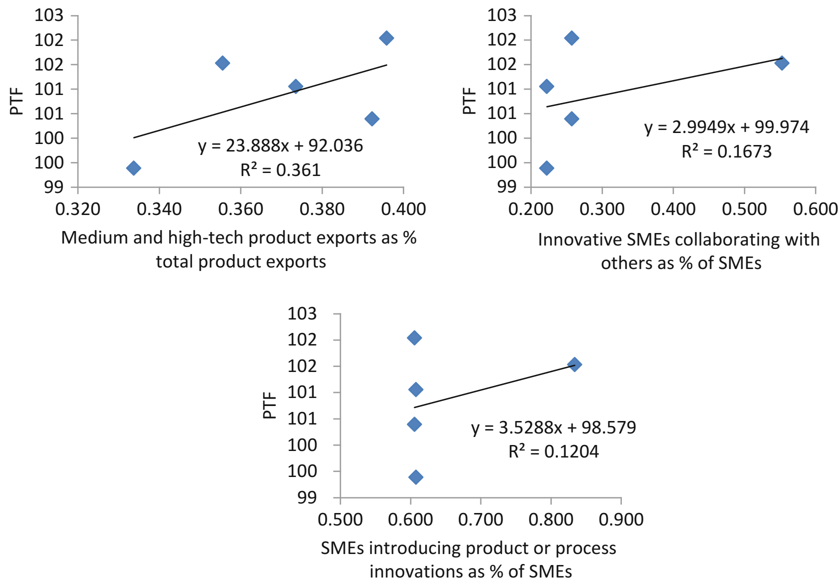
Graph 6.4 France (Centre-Est) (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

- SMEs introducing product or process innovations as % of SMEs (U-I Relations Indicator) rated 0.12.

In this sample the UIR indicators have a relative importance of 45 % and the SCE Indicator has a relative importance of 55 % in the evolution of TFP. Portugal should concentrate their efforts on the development of practices and policies that could influence these indicators (as illustrated in Graph 6.5).

The most relevant indicators associated with the evolution of TFP of Romania are:

- PCT patents applications per billion GDP (Licencing Indicators) rated 0.996;
- PCT patent applications in societal challenges per billion GDP (Licencing Indicator) rated 0.88;
- Innovative SMEs collaborating with others as % of SMEs (U-I Relations Indicator) rated 0.47;



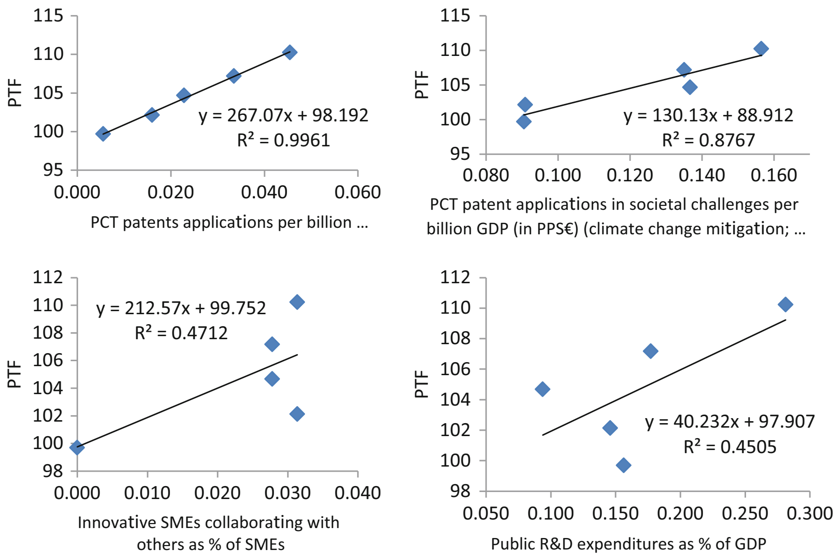
Graph 6.5 The results for Portugal (Norte) (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

- Public R&D expenditures as % of GDP (Licencing Indicator) rated 0.45.

In this sample the TL indicators have a relative importance of 83 % and the UIR indicators have a relative importance of 17 % in the evolution of TFP. Romania should concentrate their efforts on the development of practices and policies that could influence these indicators (as illustrated in Graph 6.6).

6.8 Discussion and Conclusion

TL, SCE and UIR were the 3 themes explored within this paper and fall within the wider concepts of knowledge transfer. Regional stakeholders that may have a specific remit in the area of knowledge transfer include research institutes, technology transfer offices, universities, SME's and regional and national government. This particular cohort of regional stakeholders also



Graph 6.6 The results for Romania (Bucaresti-IIfov) (*Source*: AMECO: http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm)

represents the tripe helix model (Etzkowitz and Leydesdorff 2000) which functions in the production, creation, diffusion and absorption of knowledge and innovation within a regional ecosystem. As discussed the Triple Helix Innovation Systems Conceptual Framework has been extended to include other valuable regional stakeholders such as civil society through Quadruple Helix Innovation Systems Conceptual Framework (Carayannis and Campbell 2012).

All regions have different strengths, weaknesses and attributes and the design of policies and practices to support TL, SCE and UIR within a given region needs to adhere to regional nuances. As discussed by Tödtling and Trippl (2005) there is no single best policy or practice as every region differs with regard to its innovation ability, capacity and potential. Therefore, regional stakeholders acting in line with smart specialisation policy need to focus and develop regional strengths and identify regional specialisms (O'Gorman and Donnelly 2016); as all regions cannot be successful in all areas or industry sectors and regional stakeholders should focus on being distinctive (Foray et al. 2009).

Designing and implementing effective public policy and supportive practices is difficult, as is analysing the real impact of those policies. Within the concept of smart specialisation Foray and van Ark (2007) argued against "picking winners" in case a wrong decision is made. In terms of picking which policy to implement or what practices a region should select also runs the risk of making an error of judgement. The selection tool outlined within this paper alleviates some of that selection risk; as applying the TFP to the EU Innovation Scoreboard indicators provides a robust framework that instructs which indicators should be targeted via policy and practices in order to deliver the greatest impact. If regional stakeholders understand which innovation indicators they should focus on in order to get the best return for their region, they perhaps will be guided by that knowledge in their selection of policies and practices to drive those policies.

Applying TFP to the EU Innovation Indicators is a valuable tool, however each of the regions selected in the study have to collaborate and share their knowledge and experience of practices and policies implemented in their own regions. Each of the regions in the study was selected from one of fell into one of the EU Innovation Scoreboard categories; therefore there was a sufficient mix of experience, abilities and resources between the regions (see Table 6.3). Access to this knowledge resource is key for regional stakeholders to learn quickly from the experience, mistakes and

Table 6.3 Theme performance indicator

Indicators theme	*Higher growth rate*	*Higher level*	*Recommendation*
Technology Licensing	Portugal Romania	Germany France	To improve position in relation to TLI, Portugal and Romania have higher growth; however Germany and France are the strongest performers.
Spin-Off Creation and Entrepreneurship	Portugal France	Germany Ireland	To improve position in relation to SCE, Portugal and France have higher growth; however Germany and Ireland are the strongest performers.
University and Industry Relations	France Portugal	Germany Ireland	To improve position in relation to UIR, France and Germany have higher growth; however, Germany and Ireland are the strongest performers.

Source: (Author's Own)

learning achieved in other regions of the study. This research specifically focused on knowledge transfer addressing the sub-themes of TL, SCE and UIR; however the approach can be adapted for other themes associated with innovation indicators from the EU scoreboard. The value of the approach is the direction, guidance and instruction the selection tool provides as a structured tool and rigorous framework to guide all regional stakeholders.

In conclusion, all regions within Europe face barriers to growth, innovation and development. The disparities and barriers faced by Europe's regions are varied and the approaches adopted to minimise the impact of disparity and encourage innovation, growth and development. Policy and practice design and implementation for regional innovation lacks conformity and is often driven by the preference of stakeholders within the regional or national funding agenda. Furthermore, the design of a road map of innovation based on the TFP and EU Innovation Scoreboard Indicators provides a structured and rigorous framework for regional stakeholders to address policy design, implementation and practices to meet region-specific needs.

6.9 Conclusions

All regions within Europe face barriers to growth, innovation and development. The disparities and barriers faced by Europe's regions are varied and the approaches adopted to minimise the impact of disparity and encourage innovation, growth and development are often approached in similar but different ways. Policy and practice design and implementation for regional innovation lacks conformity and is often driven by the preference of stakeholders within the region or the current funding agenda. Furthermore, the design of a road map of innovation based on the TFP and EU Innovation Scoreboard Indicators provides a structured and rigours framework for regional stakeholders to address policy design and practice implementation towards the needs of the region at any given time and not the chosen preference of individuals nor institutions within the region. The road map of innovation is applicable and transferable to all European regions and provides a framework of focus and directs a region towards the area, policy or practice that will have the greatest impact.

Appendix 6.1: List of Innovation Indicators for All Regions

Sales of new to market and new to firm innovation as a % of turnover
Non-R&D innovation expenditure as % of turnover
Knowledge-intensive services exports as % total of service exports
Venture capital (early stage, expansion and replacement) as % of GDP
SMEs introducing marketing or organisational innovation as % of SMEs
Community designs per billion GDP (in PPS€)
SMEs introducing product or process innovation as % of SMEs
Medium- and high-tech products as a % total of products exports
SMEs innovating in-house as % of SMEs
Innovative SMEs collaborating with others as % of SMEs
PCT patent applications per billion GDP (in PPS€)
PCT patent applications in societal challenges per billion (in PPS€)
Percentage youth aged 20–24 having attained at least upper secondary-level education
License and patent revenues from aboard as % of GDP
Community trademarks per billion GDP (in PPS€)
Percentage population aged 30–34 having completed tertiary education
New doctorate graduates (ISECD 6) per 1000 population aged 25–34
Public R&D expenditure as % of GDP
Sales of new market and new firm innovations as % turnover.

Note

1. Classification categories are based on the Innovation Scoreboard 2012. The European Innovation Scoreboard 2016 has re-classified the Innovation Follower category as Strong Innovators.

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CHAPTER 7

Innovation, Evaluation and Measurement: Macro-Level and Firm-Level Perspectives

Isabel Caetano

7.1 Part I—Innovation Measurement at Macro Level

7.1.1 Introduction

Innovation indicators are necessary to characterise innovation dynamics and to assess the effects of public policies supporting innovation or, from a micro perspective, return on investment, including the creation of conditions conducive to research, development and innovation (RDI) activities. Moreover, it is also important to observe the role of the different actors, whether companies, the main drivers of innovation, or other entities in the innovation system.

The systemic approaches to innovation allow us to complement and enrich the theories focused on the innovative company since, based on the reference framework proposed by the Organisation for Economic Co-operation and Development (OECD), they ensure the compiling of comparable data and indicators.

However, the fact that through measurement a company's position in different parameters of R&D and innovation is more visible may explain the current trend for developing practical application experiments by using

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complementary surveys (Baghai et al. 2008; Haanaes et al. 2009; Lay Tin 2005; Radjou 2004) and broadening the analysis beyond macro indicators.

However, despite their relevance being above all associated with a sectorial perspective, services have brought new challenges to measuring company innovation since the metrics used require the need for compatibility.

Abreu et al. (2010) note that none of the companies analysed in the study had a separate R&D budget and this fact seems to ensure a degree of "comfort". Among the reasons mentioned, the need, in the case of expenditure, to have to identify the "return" on sales stands out. Indeed, as one of the cited businessmen notes:

> . . .on the finance side everything has to have a return on sales and this will be a potential problem for me in the next 3, 4, 5 years . . . how do you justify an expenditure of several million on something that is going to give you little payback and all you are expecting is risk. (Abreu et al. 2010)

This argument to a certain extent helps to incorporate other less "enlightened" areas of innovation within companies, such as organisational innovation. Looking at 13 main types of organisational innovation, Armbruster et al. (2008) see the need to apply a different approach. Innovation surveys, overly centred on product innovation, must be revised to address this diversity. The authors argue that all companies which develop organisational innovations, regardless of whether in the last three years, must be included in the group of innovative companies under the risk of seeking to benefit the "followers".

More recently, through the emergence of the concept of sustainable innovation, there has been a noticeable adoption of metrics more aligned to organisational development perspectives, incorporating new themes such as stakeholder links, eco-innovation (energy efficiency or efficient management of scarce resources are mandatory development axes in innovation) or measuring the effects of innovation on society (Berkhout 2014; Walker and Phillips 2009).

Evaluating innovation processes becomes particularly relevant when moving from the national to the international sphere, seeking to frame regions, countries and geographical entities in joint assessment exercises that enable comparative analysis and benchmarking studies.

In recent decades, various initiatives have attempted to revise the criteria associated with the design, development and application of innovation indicators, such as the European Union's (EU's) high-level group on measuring innovation, whose results were published in September 2013.

This is an aim which other international organisations, such as the OECD, or private institutions, such as the COTEC organisations in Spain, Portugal and Italy, have also pursued.

7.1.2 Literature Review

Different authors have been studying the importance of assessing and measuring countries' technological capacities (Archibugi and Pianta 1996; Archibugi and Coco 2005; Archibugi et al. 2009; Freeman and Soete 2009). Most of the studies have focused on analysing the most important indicators applied by international organisations, such as the European Commission, World Bank and the specialised agencies of the United Nations (UN), United Nations Industrial Development Organization (UNIDO) and United Nations Conference on Trade and Development (UNCTAD) in particular. A different line of research has confirmed the existence of various works of interpretation of the situation in different countries, such as Norway (Foyn 2013), Japan (Ijichi 2013 and Fujimoto 2014), Germany (Peters and Rammer 2013), Italy (Hall et al. 2013), China (Zhang 2014), Sweden (Edquist and Zabala-Iturriagagoitia 2015) and Portugal (Godinho 2013), to mention just a few recent examples.

Archibugi et al. (2009) have focused on a number of approaches developed with a view to measuring countries' technological capacities.

The aim is to benefit from their proposed analysis, updating some of the approaches identified and introducing new benchmarks that are justified on two main grounds:

1. The fact that, unlike Archibugi et al. (2009), the purpose is to analyse innovation capacities as opposed to technological capacities;
2. The need to ensure closer alignment with the business perspective, raising the visibility of indicators that can contribute to the strategy and development of companies.

Besides the exercises carried out by the European Commission, World Bank and World Economic Forum, analysed in Archibugi et al. (2009), also identified are the approaches proposed by INSEAD, Cornell University and the World Intellectual Property Organisation consortium and by COTEC Portugal/Everis as part of the Innovation Barometer.

7.1.3 *Innovation Measurement at Macro Level: Main Instruments*

Summary Innovation Index (SII—European Commission)

The Community Innovation Survey (CIS) is the main instrument for assessing innovation activities in the EU. It is internationally diffused through the use of its indicators in various high-profile reports and assessment exercises, such as the Innovation Union Scoreboard (IUS) for example, whose structure is presented below (Fig. 7.1): Following the use of the CIS, several studies appeared that sought to analyse the effects of public innovation policies. Bearing in mind the scope of the concept of innovation and its effects, the studies generally focus on specific aspects such as the role of patents, the link between innovation and company performance, cooperation with R&D institutions, technological change and so on. However, at the heart of these surveys was also an attempt to understand innovation processes, at macro level, a particularly key aspect for the purpose of this research.

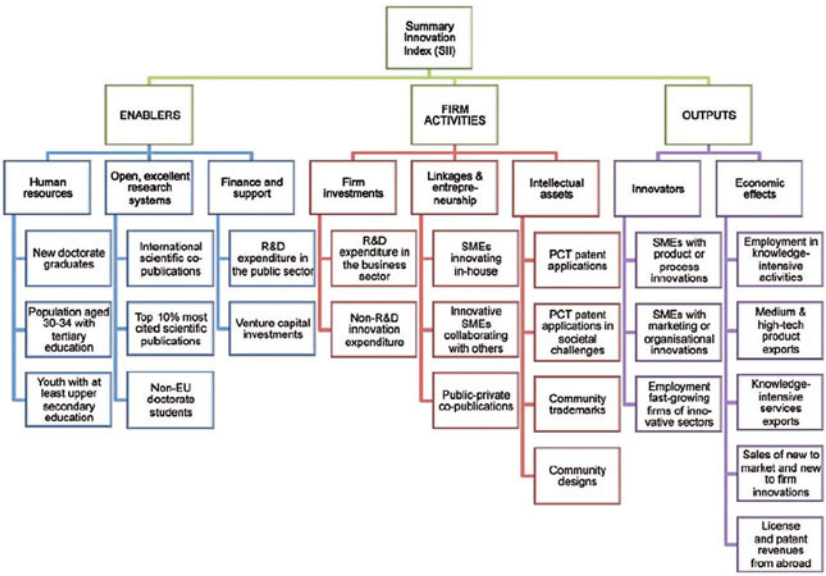

Fig. 7.1 Framework of the Innovation Union Scoreboard (IUS), 2015 (*Source*: http://europa.eu/rapid/press-release_MEMO-12-74_en.htm)

As admitted by the European Commission, the CIS aims to harmonise information on innovation at firm level, thus facilitating a macro level analysis, resulting from data aggregation on the degree of innovation in, compiling data on the degree of innovation in different sectors by type of company, types of innovation and the various aspects of development of innovation activity, such as the goals, sources of information, financing and expenditure, for instance.

Knowledge Economy Index (World Bank)

The Knowledge Economy Index comes from applying an assessment methodology—the Knowledge Assessment Methodology—proposed by the World Bank and based on four pillars deemed crucial to the creation, adoption, adaptation and use of knowledge in the economy, generating high-value goods and services:

1. Economic incentives and institutional regime;
2. Innovation and adoption of technology;
3. Education and training; and
4. Information and communications technologies infrastructure.

In the latest publication, dated 2012, it can be seen that the pillar relating to innovation and adoption of technology uses three indicators which aim to reflect the efficiency of the innovation system and based on it to assimilate and adapt knowledge to local needs or creation of new technologies:

1. Payments and receipts of royalties;
2. Technical articles; and
3. Patents (granted by the USPTO).

The Global Competitiveness Index (World Economic Forum)

The Global Competitiveness Index (GCI) is published annually by the World Economic Forum and analyses countries' competitive capacity alongside the micro economic components of their growth capacities. This assessment tool uses data compiled from an annual survey (Executive Opinion Survey) for a large number of indicators for which no available statistical data exist. In 2015, over 14,000 executives in 140 countries responded.

Based on 12 pillars of analysis, the GCI highlights the importance of innovation as a factor in economic growth and, in particular, technological innovation emerges as a defining factor in progress and quality of life. The link between innovation and competitiveness has characterised the approach developed, which is closely associated with the vision of Porter who inspired and contributed to its creation. Nevertheless, in its most recent publication (2016), GCI opens a new debate in order to update its model and to assimilate recent research results from different disciplines, including innovation.

The indicators identified also allow the different stages of development to be distinguished since for some countries the adoption and assimilation of technologies can be important while for others it is important to design, develop and market disruptive innovations that generate more value (Lev 2001; Archibugi et al. 2009).

In the innovation-related pillar (12th pillar), countries are classified according to their performance in the following areas:

1. Capacity for innovation;
2. Quality of scientific research institutions;
3. Company spending on R&D;
4. University–industry collaboration in R&D;
5. Government procurement of advanced technology products;
6. Availability of scientists and engineers;
7. PCT Patents applications

Global Innovation Index (Cornell, INSEAD and OMPI)

The Global Innovation Index (GII) emerged in 2007 out of a partnership between the University of Cornell, INSEAD and a specialised UN agency. Through its annual report, the GII diffuses the ranking of over 100 countries according to two main sub-indexes: an input sub-index (1 to 5) and an output sub-index (6 and 7) covering several pillars (Fig. 7.2):

1. Institutions;
2. Human capital and research;
3. Infrastructure;
4. Market sophistication;
5. Business sophistication;
6. Knowledge and technology;
7. Creative outputs.

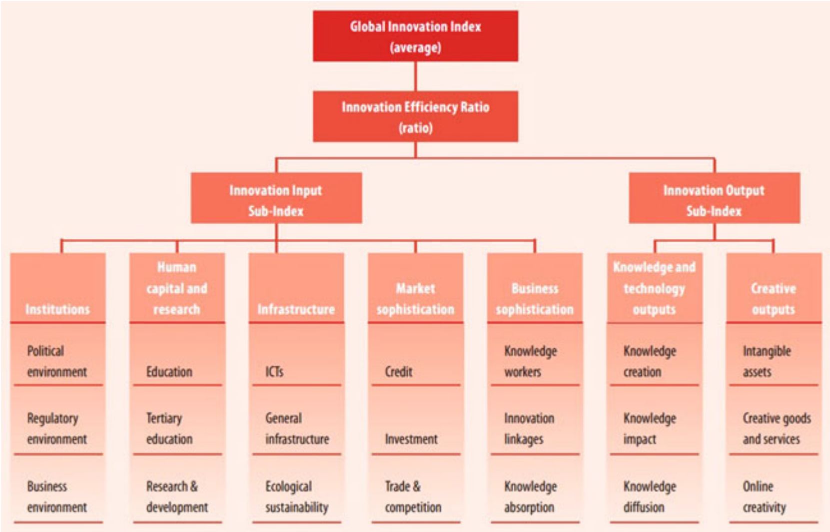

Fig. 7.2 The Global Innovation Index (GII) Conceptual Framework, 2014 in The Global Innovation Index, 2014 https://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2014-v5.pdf

The indicators proposed, as for example those included in the field of creative outputs, reveal a holistic vision of innovation since they especially highlight intangible aspects of nature frequently ignored by more traditional approaches (Dewangan and Godse 2014).

Innovation Measurement at Macro Level: A Case Study from Portugal—The Innovation Barometer (COTEC Portugal)

Since its creation in 2003, COTEC Portugal, a business association promoting innovation, has been actively involved with its associated member companies in developing a framework capable to be used at the firm level. A self-assessment and measurement system concerning business innovation performance was launched, in 2007, labelled as innovation scoring, as a way to evaluate main dimensions of business innovation (Fig. 7.3).

More recently, in 2010, in cooperation with Everis, COTEC Portugal has created a macro-level measurement instrument—the Innovation Barometer (Fig. 7.4).

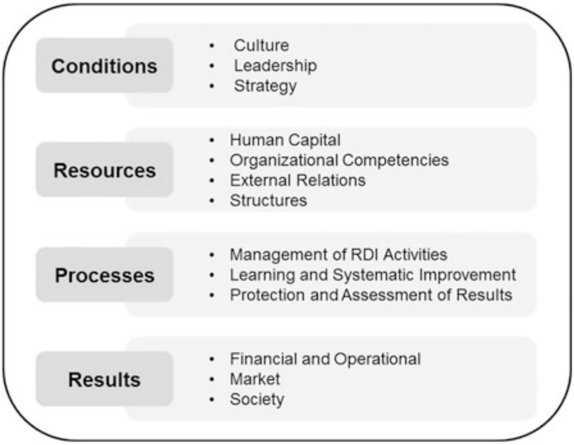

Fig. 7.3 Innovation scoring system, dimensions and pillars (*Source*: www.innovationscoring.org)

The RDI indicators model consists of 4 dimensions, 10 pillars and 67 indicators. Annually, it is presented the Innovation Digest, a consolidated ranking for the 52 countries analysed.

In the model presented, the indicators selected, from credible international sources, reveal that "Portugal's behaviour varies for each of these pillars between higher values for conditions and resources and lower values for processes and results" (Godinho 2013: 35).

Apart from the possibility to analyse each of the 52 countries considered in the Innovation Barometer and comparing their innovation performances, facilitating benchmarking, foresight and competitive intelligence exercises, it is also original in its framework, revealing the importance of innovation processes, those that guarantee R&D and technological absorption, so critical in today's digital challenges, as well as knowledge appropriation and transformation in innovations.

Comparative Analysis of Macro-Level Instruments Deriving from an input-output Approach Presented in Several Instruments

The comparative analysis of the five instruments mentioned (Table 7.1) shows that all focus on input indicators, in some cases designated "conditions", and output indicators. To a certain extent, there exists an almost

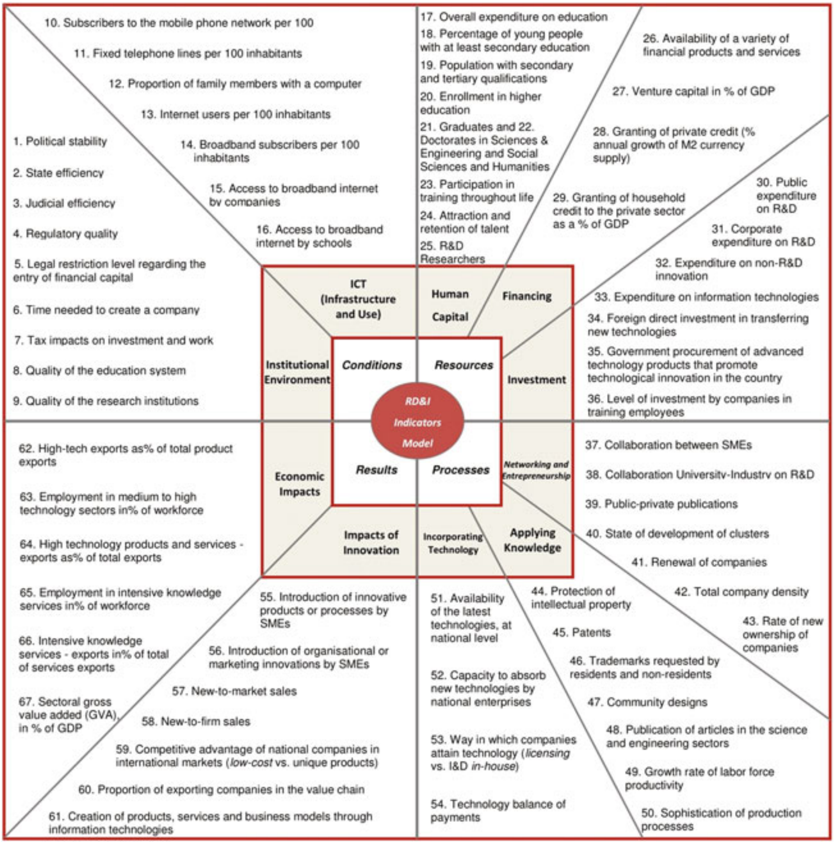

Fig. 7.4 RDI indicators model: dimensions, pillars and indicators (*Source*: http://www.barometro.cotecportugal.pt/website/statistics/index/c/statDimPilaresIndicadores)

linear view of innovation neglecting the diverse and complex nature of absorbing, transforming and valuing knowledge. However, the adoption of a more systemic approach brings a set of new indicators that the instruments used up until now have yet to totally take on board, such as the quality and intensity of the interactions established between the actors in the innovation system, only present in the Summary Innovation Digest, from the European Commission, and Innovation Digest, from the Innovation

Table 7.1 Synopsis of assessment and innovation measurement exercises

	No. of countries	*Dimensions*	*Pillars*	*Indicators*
Summary Innovation Index (SII—European Commission 2015)	28	3 (a) Enablers, (b) Firm activities and (c) Outputs	8 (a) (1) Human resources, (2) Open, excellent and attractive research systems and (3) Finance and support;(b) (4) Firm investments, (5) Linkages & entrepreneurship and (6) Intellectual assets; (c) (7) Innovators and (8) Economic effects	25
Knowledge Economy Index (World Bank)	146	–	4 (a) Economic Incentive and Institutional Regime, (b) Education, (c) Innovation and (d) Information and Communications Technologies	109
Global Competitiveness Index (World Economic Forum)	144	3 (a) Basic requirements sub-index, (b) Efficiency enhancers sub-index and (c) Innovation and sophistication factors sub-index	12 (a) (1) Institutions, (2) Infrastructure, (3) Macroeconomic environment and (4) Health and primary education; (b) (5) Higher education andtraining, (6) Goods market efficiency, (7) Labour market efficiency, (8) Financial market development, (9) Technological readiness and (10) Market size; (c) (11) Business sophistication and (12) Innovation	114
		2	7	

(*continued*)

Table 7.1 (continued)

	No. of countries	*Dimensions*	*Pillars*	*Indicators*
Global Innovation Index (Cornell, INSEAD and OMPI)	143	(a) Innovation Input Sub-Index and (b) Innovation Output Sub-Index	(a) (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication and (5) Business sophistication; (b) (6) Knowledge and technology outputs and (7) Creative outputs	81
Innovation Digest–Innovation Barometer (COTEC Portugal/Everis)	52	4 (a) Conditions, (b) Resources, (c) Processes and (d) Results	10 (a) (1) institutional environments (2) ICT (infrastructure and use); (b) (3) Human capital, (4) Financing and (5) Investment; (c) (6) Networking and entrepreneurship, (7) Application of knowledge and (8) Incorporation of technology; (d) (9) Innovation impacts and (10) Economic impacts	67

Barometer, the valuing of knowledge and the economic and social effects and impacts. Various limitations have therefore been identified (Edquist and Zabala-Iturriagagoitia 2015).

Innovation Measurement at Macro Level: Challenges and Limitations

National and international business cases reveal the diversity, originality and reach that innovation achieves. To attempt to find a single approach that captures the results of innovation is a challenge considered by many an impossibility. The systemic nature of innovation requires the use of diverse indicators able to reflect this reality and allow more margin for experimentation (Salter and Alexy 2014; Simões 2008; Pereira 2007), one of the reasons behind the emergence of various assessment exercises. Therefore, alongside the development of the IUS, innovation surveys and other assessment tools have been used that adopt various methodologies in an attempt to apply new indicators, especially those related to output.

Despite the progress achieved, the approach used in Europe, above all centred on the IUS, reveals several limitations, one of the most important of which is its difficulty in adjusting to a systemic model and its effects and measuring the dynamics of the actors, interactions and differences in the various countries. The European Commission itself recognises that new situations exist to which it is unable to respond using the existing assessment tools, such as for example the need to analyse rapidly growing companies and the need for greater international coverage, bolstering the link to the OECD.

Both Archibugi (2009) and Edquist and Zabala-Iturriagagoitia (2015) also stress that the use and "abuse" of the indicators related to technological capacities, despite the merit stemming from the possibility to swiftly identify each country's "place" in a ranking, complicate a more comprehensive analysis of the innovation process, including the main knowledge production, assimilation and dissemination mechanisms.

On the subject of the place occupied by Sweden in the SII, Edquist and Zabala-Iturriagagoitia (2015) note the following:

> We argue that the Summary Innovation Index provided by the IUS is highly misleading. Instead of merely calculating this Summary Innovation Index, the individual indicators that constitute this composite innovation indicator need to be analysed in much greater depth in order to reach a correct measure of the performance of innovation systems. We argue that input and output indicators need to be considered as two separate types of indicators and each type should then be measured individually. Thereafter the input and output indicators should be compared to one another, as is normally done in productivity and efficiency measurement.

A comparative analysis of the ten leading countries in the five innovation indices (Table Table 7.2) selected allows use however, to find major convergence in terms of the countries' positioning, suggesting a similar methodological approach. In 2005, Archibugi and Coco noted the importance of basing measurement, via the selection of indicators, on a theory able to link technological capacities with economic and social performance. Observing

Table 7.2 Leading countries in the approaches analysed (1st to 10th place)

Summary Innovation Index (SII—European Commission)	*Knowledge Economy Index (World Bank)*	*Global Competitiveness Index (World Economic Forum)*	*Global Innovation Index (Cornell, INSEAD and OMPI)*	*Innovation Digest—Innovation Barometer (COTEC Portugal/Everis)*
The Innovation Union Scoreboard 2015	Knowledge Economy Index 2012 Innovation Pillar	The Global Competitiveness Report 2015–2016 Innovation Pillar	Global Innovation Index 2015	Innovation Digest 2015
Sweden	Switzerland	Switzerland	Switzerland	Switzerland
Denmark	Sweden	Finland	UK	Denmark
Finland	Finland	Israel	Sweden	Finland
Germany	Singapore	USA	Netherlands	USA
Netherlands	Denmark	Japan	USA	Ireland
Luxembourg	USA	Germany	Finland	UK
UK	Netherlands	Sweden	Singapore	Sweden
Ireland	Israel	Netherlands	Ireland	Germany
Belgium	China (Taiwan)	Singapore	Luxembourg	Luxembourg
France	Canada	Denmark	Denmark	Korea

the various exercises, it can be seen, as Edquist and Zabala-Iturriagagoitia (2015) note, that in the SII approach, in most of the innovation indices, no analysis of the efficiency and productivity of the innovation systems exists. Moreover, all the indicators considered were often given the same weight and no distinctions are made about which indicators measure various innovation components, such as inputs, processes and results, besides innovations per se. In Portugal's case, with the inclusion of differentiated weighting for the various analysis dimensions in the Innovation Barometer, it was observed an attempt to centre the innovation measurement analysis on the efficiency of the system.

As far as the challenges are concerned, the systematisation of the main innovation models, as well as the innovation indicators, allowed a first view of their scope to be established. Indeed, based on the analysis of the different innovation typologies, it was possible to conclude that no set of assessment metrics exists in the literature associated with them. There are few metrics which resist the various innovation typologies presented and allow the full effects of innovation to be assessed. In fact, as can be observed at the business scale, organisational innovation is one of these examples since there are various particularities inherent to its effects, such as the temporal effect stemming from its life cycle being different from other types of innovation (Armbruster et al. 2008).

Edquist and Zabala-Iturriagagoitia (2015) admit that the measurement of the performance of innovation systems must reflect both the characteristics of the innovation, in terms of input, and the results of innovation, often assumed as outputs.

Also when considering GCI challenge to update its model, it is still difficult to observe how a new measurement model capturing competitiveness is proposed, independently of an "input–output" model or a resources-based approach. Focusing on an innovative sustainability approach could require a more diverse and multidisciplinary effort in order to capture innovation intangible effects and externalities. In spite of admitting the need to apply a broader notion of innovation, as it is evident since the Oslo Manual edition from 2005, GCI still misses a holistic view of innovation. Ideas generation and implementation, being relevant to innovation culture and dynamics, are drivers of innovation together with other critical determinants that cannot be neglected.

Furthermore, as we can analyse at firm level, other results may be valued such as social impact, the influence of reputation and image, as it is more and more evident when marketing campaigns are designed in close association to innovation driven strategies, or the contribution of innovation to organisational efficiency or to scientific and technological progress.

From the limitations identified, as well as the challenges they present, including for business actors, the opportunity exists to develop an approach capable of ensuring, progress in the assessment and measurement of return on innovation. Financial metrics, such as NVA (Net Value Addded) or Return on Investment (ROI), are already being used in different situations, including the assessment of social innovation projects. However, the link between the various analysis perspectives—macro, sectoral and business—may illuminate other "measurement" areas that are difficult to identify in isolation.

Another important challenge has to do with the purpose of measurement. Previous research studies (Dodgson et al. 2014), stress the importance of differences between sectors and the need to analyse firm activities, strategic objectives and interactions. Indicators have been studied in order to better understand innovation systems and its main performers, gradually more active in collaborative initiatives, including clusters and platforms

(Gault 2013). With regard to services, it is accepted that a huge group of activities are not covered by the more traditional metrics, such as the use of ICT and their impact on creating innovation. New metrics must emerge that respect four main criteria: accuracy, longevity, comparability and ease of data gathering (Abreu et al. 2010).

In addition, the metrics described illustrate another of the challenges that need highlighting. The difficulties intrinsic to gathering data of this nature illustrate the lack of response, even in the proposed metrics just mentioned, such as VAL and ROI, to the measurement of intangibles such as knowledge or social and human capital (Lev 2001).

7.2 Part II: Innovation Measurement at Firm Level[1]

7.2.1 Introduction

Innovation is generally accepted to be linked to differentiation, competitiveness and value creation. Nevertheless, it is widely recognised as a difficult domain to assess and to measure. At firm level, most companies are eager to develop and apply specific methodologies contributing to capture innovation results effects. A major problem in innovation management is how to do it.

Different contributions resulting from academic research and empirical work justify the need for a deeper understanding of innovation evaluation and measurement, in some cases resulting from a systematic analysis of innovation indicators through different lenses at a macro, sectorial or business levels, as previously observed.

In spite of progress achieved, mainly through management practices based on innovation indicators, as it is the case for decision-making processes (e.g. at ideas or project selection in innovation management), a harmonisation that can be applied at business level is needed. Seminal research focusing on econometric approaches (Mansfield et al. 1971; Leonard 1971; Griliches 1979; Cordero 1990; Hall 1996; David et al. 1999) identified this problem and its relevance. Several studies developed a review of research previously dedicated to innovation measurement, mostly devoted to R&D results (Hall et al. 2010, 2013; Chiesa and Frattini 2009) and also to innovation determinants and related indicators influencing results (Carayannis and Provance 2008; Adams et al. 2006; Milbergs and Vonortas 2005). Also, as demonstrated by case studies concerning innovation management relevance (Dewangan and Godse 2014; Gama et al. 2007), companies experience difficulties to measure innovation outputs, especially intangibles, even when applying management tools as the Balance Scorecard. In the field of strategic management, research examines different appropriability mechanisms (patents, secrecy, lead time and complementary assets), contextual conditions and outcomes (Teece 1986 and 2009; Al-Aali and Teece 2013; James et al. 2013).

As admitted by Adams et al. (2006), there is a lack of clarity in the use of indicators and metrics by researchers and business managers. A main difficulty is also experienced in developing a framework through which those indicators and metrics can be applied as innovation management tools, facilitating comparability and bench learning. The absence of such a framework, together with risk, uncertainty and complexity that characterises innovation (Salter and Alexy 2014), opens a research avenue requiring a systematic literature review and a syncretised approach permitting that different perspectives contribute to an overall encompassing innovation management measurement approach.

7.2.2 *A Syncretised Approach Towards Innovation Management Measurement*

Relevant contributions from different theories and management and economic thought schools more than alternatives are complementary views that contain hypotheses that can be explored and integrated into a measurement framework.

Consensual stylised facts about innovation, based on results from empirical research, include the uncontroversial statement that capturing return on innovation is a complex goal (Salter and Alexy 2014).

Innovation indicators, have also been substantially studied when considering a macro-level perspective and analysing regions and countries' performance (Archibugi and Pianta 1996; Archibugi and Coco 2005; Milbergs and Vonortas 2005; Archibugi et al. 2009; Freeman and Soete 2009). At country level, several studies followed this research strand, focusing on innovation performance from Norway (Foyn 2013), Japan (Ijichi 2013 and Fujimoto 2014), Germany (Peters and Rammer 2013), Italy (Hall et al. 2013), China (Zhang 2014), Sweden (Edquist and Zabala-Iturriagoitia 2015) or Portugal (Godinho 2013) just to illustrate some examples.

The idea that there does not exist a unique theory capable of explaining such a complex phenomenon as innovation is the motto for our assumption and that there is a need for a syncretised approach towards innovation management measurement.

Importance attributed to institutions (Dosi and Orsenigo 1988; Nelson, 1991), to evolutionist approaches (Nelson and Winter 1982) or to systemic perspectives (Freeman 1987; Lundvall, 1992; Edquist 1997; Teece 2010), in spite of being explored according to specific research problems, can be used as theoretical contributions for this innovation management approach.

On the other hand, the influence of open innovation perspective on management (Chesbrough 2003) emphasised the need to analyse innovation results in strategic terms, highlighting its effects on reputation, image and other intangible assets, apart from contribution to firms performance, as well as the importance of generating a new innovation model adapted to recent challenges and transformations.

A simplified input–output approach cannot capture anymore the diversity, permeability, due to openness and interdependence resulting from collaboration, and complexity of innovation activities. Open innovation induces a real impulse for improving a better connection with theories of management, emphasising changes in the way firms own, control and leverage their resources to create competitive and transient advantages (Barney 1991; Grant 1991; McGrath 2013; Alexy and Dahlander 2014). In parallel, digital transformation generates disruptions that companies must consider and embrace in their innovation management models (Westerman et al. 2014).

Main instruments targeted to assess and to measure innovation in a macro level perspective, designed by international organisations (OECD, European Commission, World Bank, etc.) must evolve to assume these shifts, including new indicators to better capture firm innovative activities and performance. Academy has already adopted several business cases revealing business practices aligned with those influences, as P&G, IDEO, GORE-TEX, ARUP and LEGO are examples. A common characteristic of those business cases results from the fact that companies analysed inserted innovation in business strategy, supported by the development of a creative, relational and open models.

Companies, remaining the most relevant innovation actors, mainly deriving from their market and value creation orientation, are effectively absorbing major changes in the innovation life cycle and the role different actors can play in a more open and dispersed context. New opportunities, market, technological, societal, put pressure on innovation management due to multiple sources, actors and influences (Dodgson et al. 2014). Since

2008, a Multichannel Interactive Learning Model (Caraça et al. 2006) has been adopted by almost 200 companies in Portugal following its application as a basis for an innovation management system for audit certification by third parties.

Our research aims to analyse how companies are managing innovation, which practices and processes have been implemented and what framework could be designed to promote their capabilities to evaluate and measure innovation.

7.2.3 Methods

In a first stage, in order to better understand how companies manage innovation and which practices have been used, a questionnaire was emailed to firms operating in Portugal, members of a Portuguese business association promoting innovation, as a proxy for Portuguese most innovative companies, and a total of 136 valid responses were obtained, approximately 50 % of the sample.

The questionnaire targeted three main axes:

1. Business strategy and innovation;
2. Management practices connected with innovation activities and projects;
3. Accounting methods applied.

Both cluster and multiple correspondence analysis (MCA) developed, showed that the selected variables (ten in total) have convergent validity, all measuring the index innovation itself. These variables apply to the principal object of measurement, and the initial exploration developed under this research, using statistical techniques previously presented, proved the validity of the survey conducted by its suitability for the purpose of study, complemented with the application of focus group exercises under the pilot group, and interviews in the companies, mainly Innovation Managers and Financial Managers, considered in previous studies as key informants (Gatignon et al. 2002), that led to the formation of aggregates considered in terms of maturity of the companies in the field of innovation management.

Our cluster analysis, as an exploratory technique that can be used to detect homogeneous data groupings based on differences from selected variables, could permit, as theory suggests, to explain distances, correlations and associations observed, maximising not only cases of homogeneity in the same group but also heterogeneity between groups.

Nevertheless, as variables selection determines clusters characteristics, our analysis, based on variables showing a high multicollinearity, due to its measurement object being "innovation", was complemented with a MCA. Through this analysis, was studied relations between dichotomised variables associating optimal quantifications that maximise categories separation, facilitating its representation in a few dimensions.

The index innovation verifies unidimensionality, through dimension 1 showing a Cronbach's alpha =0.753, and convergent validity due to the fact that all variables represent the same concept, quantified by eigenvalue >1 (Table 7.3).

Due to the high multicollinearity between variables (variance inflation factor >3, correlations between variables > 0.85), the small differences among companies in the ten variables (see Appendix A) are explained by others variables which belong to the questionnaire but are not included in this latent factor, allowing us to consider five aggregates (Fig. 7.5):

Absorbing insights from the Capability Maturity Model Integration (CMMI) methodology, as presented in Fig. 7.6, developed by Carnegie Mellon University and initially applied mainly in engineering sectors, it was

Table 7.3 Summary model—mean Cronbach's Alpha is based on the mean Eigen value

Summary model			
Dimension	*Cronbach's alpha*	*Explained variance*	
		Total (Eigen value)	*Inertia*
1	.753	3.102	.310
2	.232	1.264	.126
3	.093	1.091	.109
4	.022	1.020	.102
5	-.135	.891	.089
6	–.238	.824	.082
7	–.400	.735	.074
8	–.705	.612	.061
9	–.956	.537	.054
10	–1.137	.494	.049
Total		10.571	1.057
Mean	.060[a]	1.057	.106

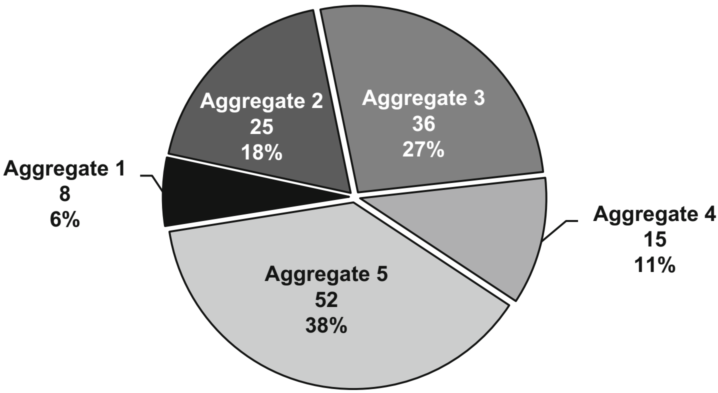

Fig. 7.5 Sample distribution by aggregates

possible to identify, through variables considered and respondents' data, different maturity levels concerning innovation management.

In what concerns objectives and maturity in Research, Development and Innovation (RDI) activities, our analysis used the aggregates already indicated in Fig. 7.5, considering that companies included in each cluster are similar and differentiate from others.

An examination of each aggregate, corresponding to companies showing a similar profile, maturity level and strategic support to innovation, was developed. Each aggregate was constructed through the combination of 10, in a total of 18, different closed answers (Yes/No). Those ten structured answers, from the survey applied, included in the three axes above mentioned, were considered as variables for this analysis.

Also, considering the need to learn from practice and to experiment measurement approaches, a pilot group of 7 companies was launched. It was formed in order to guarantee a facilitation network that enabled not only the focus group exercises but also the interviews and the validation and test of a preliminary evaluation measurement framework. This procedure previously used in the design of business performance measurement (Neely et al. 2000; Gatignon et al. 2002) permitted a participatory process through which companies from different sectors could share their processes and practices (Table 7.4).

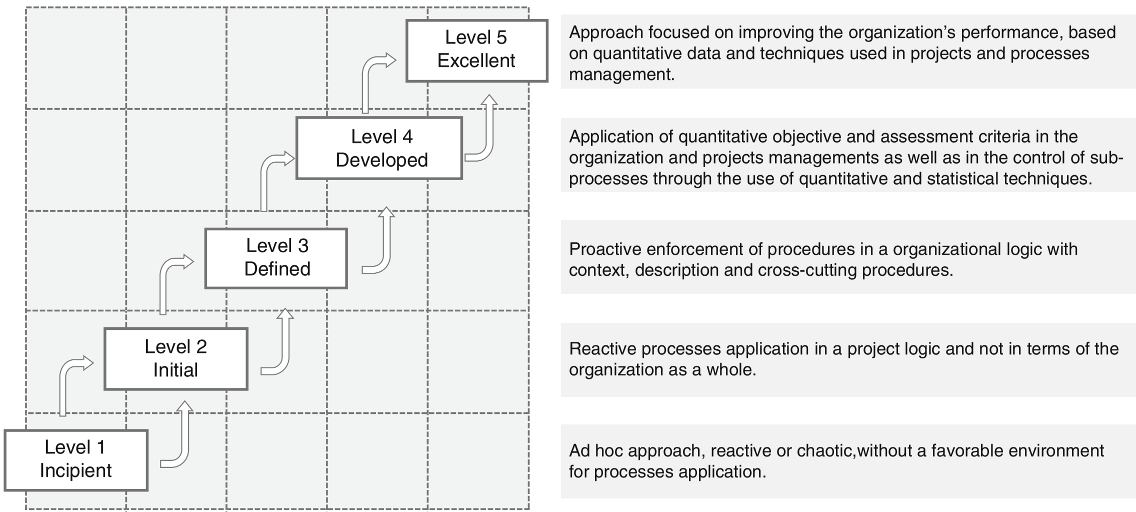

Fig. 7.6 CMMI methodology—maturity levels in innovation management (Software Engineering Institute 2010)

Table 7.4 Summary of the characterisation of the Pilot Group

Pilot Company	Type of Innovation	Tools of R&DI Management	Indicators	Project Selection	Transversal Risk Analysis	Accounting
Company 1	Service / Process	■	■■	■■	■■	■
Company 2	Service	■■	■■	■	■	■
Company 3	Product	■	■	■■	□	■■
Company 4	Process	■■	■■	■	■■■	■■
Company 5	Organisational	■■	■	■	■■	■■
Company 6	Organisational	■■	■■	■	■	■
Company 7	Organisational Service Marketing	■■	■■	■■	■■■	■■

Maturity Level

Incipient / Not developed	□
Initial	■
Defined	■■
Developed	■■■

7.2.4 *Findings*

Maturity Levels in Innovation Management

The first finding, obtained from survey results and from experimentation within the pilot group, is that companies show different innovation management maturity levels, characterised by their strategic, operational and financial approaches. Through survey results, it was possible to aggregate respondent companies, in total 136, in five different groupings, business "clusters", and to identify their specific innovation management practices and proficiency. The identification of maturity levels followed the CMMI methodology and guidelines concerning product development as a proxy for a broader application in innovation management, taking profit from the fact that it envisages the development and sustainability of a measurement

Table 7.5 Maturity levels in innovation management

Business "clusters"	*Stage*	*Maturity level*
Cluster 1	Incipient	1
Cluster 2	Initial	2
Cluster 3	Defined	3
Cluster 4	Developed	4
Cluster 5	Hybrid	–

capability supporting specific processes and information needs (CMMI Institute 2015) (Table 7.5).

Different maturity levels in innovation management capture a broad range of practices and processes. Through our analysis, we cannot conclude that less developed companies, in terms of innovation measurement, are less innovative. Nevertheless, those companies revealing more structured approaches have already in place seeds for RDI performance evaluation and measurement. As identified in the pilot group cases, all the companies, even if not very developed as demonstrated in Table 7.4, use innovation management tools and apply RDI indicators. In terms of accounting, some companies have identified and defined the relevance of implementing accounting analytical procedures but have still a long way to achieve a mature and developed framework capable to capture innovation impact and its value. A group of companies was designated as a "hybrid" group as they do not fit to the previous standardised groups already characterised, as they are not incipient but they are neither mature, demonstrating a confused innovation management profile (Table 7.5).

Our analysis has also shown that the five different business *clusters* reflect distinctive approaches towards innovation management (Table 7.6).

At a first level, an incipient stage gathered those companies that do not include innovation as a key driver for global business and strategic management.

At the next level, another group of companies was formed by those companies in which analytical accounting is not yet applied to RDI activities and projects, thus creating difficulties to a measurement exercise.

Under level 3, a group of companies having in place more developed innovation management practices, differentiate as they apply also several measurement indicators and metrics, directly linked to their accountancy guidelines and financial department. Innovation is assumed as a strategic driver for the organisation and that implies an alignment of management practices as routine operations, ensuring a more fertile environment for assessing and measuring innovation results.

Table 7.6 Innovation management processes: clusters analysis

Innovation management processes	*Cluster 1*	*Cluster 2*	*Cluster 3*	*Cluster 4*	
Strategic approach to innovation	x	√	√	√	Business strategy
Innovation plan	x	√	√	√	
Innovation management indicators	x	√	√	√	
Other management indicators or metrics to assess innovation impact	x	x	x	√	
RDI projects—quantitative evaluation	x	√	√	√	Innovation activities and projects
RDI activities (apart from projects)—quantitative evaluation	x	x	x	√	
Technologies and tools supporting innovation management	x	x	x	√	
R&D accounting (cost accounting in analytic terms)	x	x	√	√	Accounting
R&D accounting process applied to provide investment, cost and profit analysis associated with R&D projects	x	x	x	√	
RDI accounting (apart from R&D)—specific financial analysis	x	x	x	√	

At level 4, a small group of companies, about 11 % of those inquired, revealed that there are cases in which a holistic measurement exercise is tried, as those companies demonstrate that innovation is embedded in its culture, embracing and stimulating innovation as a transversal value for all the organisations.

As indicated previously, the questionnaire targeted three main axes, business strategy, innovation activities and projects and accounting methods applied by the companies surveyed. The variables considered, linked to specific questions introduced in the questionnaire, permitted to elaborate an analysis, as presented in Table 7.6, of the innovation management processes those companies apply.

CMMI Application Main Lessons

The application of maturity models in the domain of innovation enabled to develop and analyse a framework, combining maturity levels at firm level with capabilities to develop a ROI approach. Designed as a matrix, the framework helps to identify companies positioning in five different levels according to their innovation management proficiency and their assessment and measurement capacities, especially when considering a ROI approach to RDI activities.

Initially applied in information technologies, namely in software development processes, CMMI enables a maturity assessment in different management domains, extending its original focus. Business practitioners and consultants have already assimilated this possibility (Planview 2014), highlighting its potential to improve performance monitoring and measurement. It facilitates evaluation through the identification of business areas that can be considered more critical. Levels used in CMMI facilitate the analysis of trajectories for organisations willing to improve their products or services acquisition, development or commercialisation.

RDI activities reveal normally high complexity and the need to manage it, facilitating to reduce uncertainty and risk as well as to support better and evidence-based decisions, led to the application of different management models.

The appropriation of CMMI and its application in business innovation enabled the development of a framework, presented in Fig. 7.7 that combines: (1) the maturity levels in innovation management and (2) the capability levels in innovation evaluation and measurement. In a simplified tool, companies and organisations can position themselves and identify its proficiency according to these two main lenses.

Innovation Activities: Focus on Projects

Measuring innovation results requires then an adequate accountancy process and respective methods for assessing costs and profits associated with innovation activities. As recently assumed by Perani (2015), Oslo Manual revision must capture users' needs for a better measurement of innovation outcomes, matching and integrating different approaches towards a multi-stage mechanism.

Under this "umbrella" of Oslo Manual revision, intangibles are emerging as a new dimension, complementary to innovation costs. Also, relevance of a more holistic perspective, highlights open innovation effects as a phenomenon that must be evaluated and measured.

Projects have been identified, in literature as well as in practice, as "measurable entities" that can more easily accommodate a formal and systematic evaluation procedure, frequently associated with its funding rules and its management standards (as required by International Projects Management Association or Project Management Institute organisations).

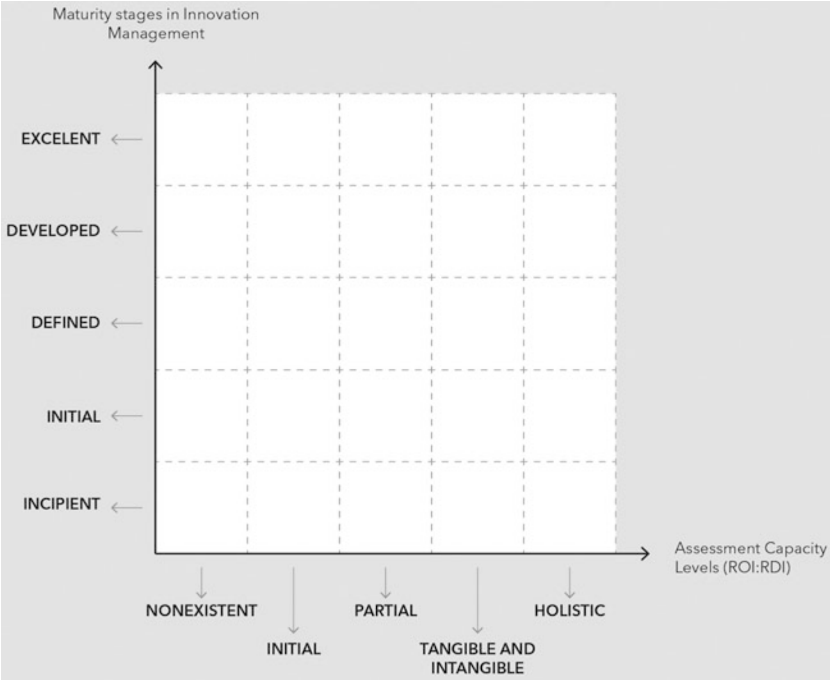

Fig. 7.7 Innovation measurement at firm level—maturity and ROI assessment capacity levels

A ROI approach to innovation, based on the conventional ROI formula,[2] could then be applied to innovation projects, representing most of innovation activities at firm level, including at an open innovation mode.

Nevertheless, it was observed that evaluation "time" is not consensual. Post project evaluation, generally up to three years after project conclusion, is considered adequate as most project results will be already disseminated and its measurement will be easier. Specificities from R&D&I activities developed in some domains, as pharma or biotech, could require a different evaluation time. Contributions from several authors, as Shenhar and Dvir (2007); Chiesa and Frattini (2009), emphasise that business goals and sectors influence project characteristics and there is a need to maintain several evaluation methods in order to address diversity, complexity, implementation, costs and other decision criteria when facing project evaluation.

Apart from a posteriori measurement, firms can also apply an a priori ROI approach, before project launch. Firms tend to absorb tools and methodologies which can contribute to reduce uncertainty, to assess risk and define strategies to maximise project success, to improve knowledge concerning potential projects results and to enable better decision-making in order to guarantee minimum rates of return.

Innovation Indicators

Innovation dynamics raised the need to have indicators and metrics contributing to analyse, evaluate and compare its different expressions and impact on performance and competitiveness.

According to the research problem identified, management practices from companies analysed have shown that they apply several indicators, being the most common the weight of new or significantly improved products (measured by the ratio: Sales of new or significantly improved products/Turnover).

In line with previous research developed at COTEC Portugal (Caetano, 2010), many companies having implemented a formal innovation management system, audited and certified by external parties, absorbed and applied several indicators and metrics described in literature. In some cases, surveys and qualitative methods complement and enrich evaluation initially based on indicators. In specific innovation types, as organisational or services innovation, it is also assumed that generalised surveys are not adapted.

Nevertheless, apart from its nature being more linked to conditions, as input indicators, to processes, as throughput indicators, or to results, as outputs indicators, companies do not have in place a systematic process to evaluate and measure, regularly, its innovation effects.

7.2.5 Towards an Evaluation and Measurement Framework: Extracting Lessons from Practices

Following the application of the interactive innovation management model in Portugal (Caraça et al. 2006), our evaluation and measurement approach captures its main contributions, highlighting not only the importance of "context" in which firms operate but also the innovation determinants and the innovation process cycle which can be considered as its main building blocks.

Companies surveyed and pilot group cases studies have shown the possibility to implement an evaluation and measurement framework

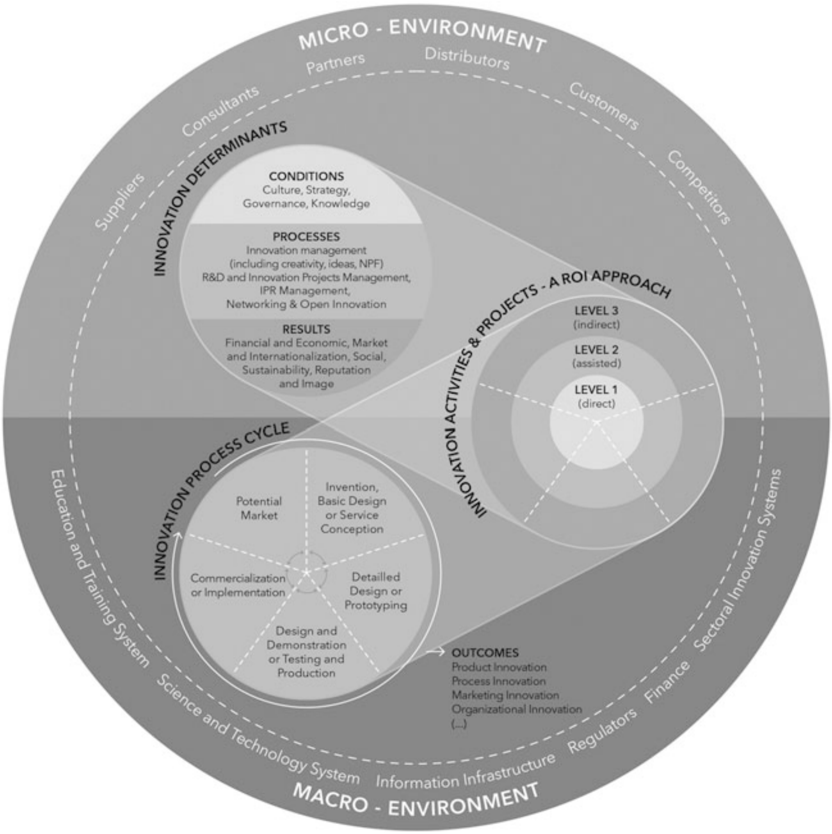

Fig. 7.8 Innovation measurement at firm level—a return on innovation approach

concerning innovation activities. Nevertheless, it was clear that those companies that have not in place management processes as routines, including its linkages with accounting guidelines, demonstrate less developed capabilities to implement that type of framework, namely if it is foreseen to analyse tangible and intangible effects as proposed in levels 2 and 3 from our model, as described in Fig. 7.8, considering an application of a ROI approach to innovation activities and projects.

Many companies, approximately 60 % of respondent, already use a self-assessment generalised in Portugal, the innovation scoring system promoted by COTEC Portugal and IAPMEI. Nevertheless, in spite of supporting innovation management and guiding an internal diagnosis concerning innovation determinants (Smith et al. 2008; van der Panne et al. 2003), this tool does not capture value created by innovation.

The model proposed addresses those limitations and includes the business innovation cycle in its context as firms are not isolated units. A systemic approach facilitates then our understanding of the different components represented and its linkages, influences and interdependences with micro and macro environment elements:

1. Innovation Business Determinants: innovation evaluation and measurement at firm level, as previously suggested by researchers (Adams et al. 2006; Dervitsiotis 2010; Muller et al. 2005), must include a regular and systematic process addressing innovation determinants included in a broad spectrum of areas, for example culture, strategy, governance, processes and innovation results.
2. Innovation Process Cycle: transformation of ideas and knowledge into innovative results (product, process, organisational, marketing, social, business model innovations, etc.) requires a formalised process, normally associated with new product development methodologies that reflect also evaluation and measurement in order to check the agility, speed, flexibility and capabilities in maintaining a healthy innovation portfolio, in an ambidextrous perspective, as a relevant axis of business sustainability.
3. Innovation Activities and Projects: innovation activities and projects are at the core of innovative firms. In our model, a ROI approach can be applied to this building block as it is possible to link to accounting procedures in order to evaluate and measure innovation effects in different levels, including the possibility of associating direct costs and profits to the activity or project that is subject to analysis.

Research developed has contributed to identify, through a systematic analysis of literature, survey answers, focus group interviews and its linkages to the innovation scoring main dimensions and pillars (COTEC Portugal 2007), innovation determinants to be evaluated and measured. A framework, reflected in Fig. 7.8, apart from the application of a ROI approach to innovation activities and projects, can encompass broader measurement areas contributing to characterise an innovative performance at firm level as well as the innovation process life cycle.

7.3 Conclusions

This research contributes to the understanding of innovation measurement at business level and its relevance to a more systematic approach towards innovation management, identifying specific innovation indicators and generating knowledge on how companies can apply an evaluation methodology. Considering innovation as a critical resource contributing to a sustainable competitive advantage, its influence on business performance, namely in value creation, puts pressure on managers to apply an evidence-based methodology to evaluate and to measure innovation results.

Innovation management is challenged by the power of demonstrating its value, showing return on investment and giving evidence-based information and data supporting business decisions and options concerning innovation activities.

Cases from the pilot group have highlighted that innovation measurement is a difficult and extremely complex task, requiring different competences and processes in order to pursue that goal. Some of these difficulties are related to the need to find and to apply innovation indicators that can be transversal. In fact, the nature and the type of projects or other innovation activities could require specific indicators but in order to achieve a common and holistic framework, innovation indicators must be independent regarding diversity, at least at macro level. By that reason, in spite of most companies' effort to apply some general innovation indicators, innovation projects are identified as the most appropriate units to implement specific innovation indicators targeting outcomes and impact as well as to apply a ROI approach.

Our research also identified that isolating innovation impacts from the global business activities is not easy due to several aspects. First of all, time is a key ingredient to be considered in the measurement exercise and RDI activities are frequently developed in a long-term perspective. The time range to assess and measure RDI impact should be defined and aligned with the measurement process, which is not consensual between companies, sectors and innovation types (product, service, process, organisational, marketing, social, etc.). Also, information systems and technologies applied at firm level, mostly as decision support systems, enable to get a picture of the moment but hardly achieve to facilitate a prospective view concerning future impact of RDI activities and projects.

In what concerns innovation measurement and its linkage to accountancy guiding principles, it was noted that companies are aware that RDI costs should be identified and clearly specified in financial terms. In fact, public policies concerning tax incentives for R&D favoured this procedure. Nevertheless, it was observed that RDI profits are not, as costs, so clearly stated in close connection with the activity or project that originated it. Most companies reveal serious problems when trying to differentiate and measure tangible and intangible profits. Issues as costs reduction or business growth due to customers' loyalty related to innovation results are practically ignored in most companies. Indicators measuring intangibles are almost inexistent in innovation management measurement practices from the companies analysed, as it is the case concerning trademarks, brands or reputation.

Through a better understanding of the innovation management maturity levels, and specific processes linked to different proficiency stages, managers can absorb and apply practices and processes as enablers for a more robust and systematic innovation management. Also, for those organisations adopting a specific ROI: RDI methodology, a formal coordination between different departments or functions, as it is the case of HR, Marketing, RDI, Financial and so on, will be stimulated in order to evaluate, in its broader context, innovation results and effects.

In sum, the results obtained confirm that there is a need to further develop research exploring connections between innovation determinants, innovation life cycle dynamics and innovation performance measurement in terms of a ROI approach. The presented framework could also be further applied in order to be revised and validated in terms of its practical usefulness and acceptability. Return on investment indicators linked to innovation activities and projects should be systematised and tested, detailing costs and profits that could be associated with the three levels of evaluation and measurement (direct, assisted and indirect) and a portfolio of possible indicators and metrics could be provided.

When admitting a "Mode 3"systems approach (Carayannis and Campbell, 2012), even if departing from firm level, innovation can be analysed and measured in a broader context in which *soft power* determinants, including culture and values, are crucial, as the "quadruple helix" advocates. A new innovation measurement model as presented in Fig. 7.8 covers not only those "modes", in which actors assume different roles, but also a non-linear representation of the innovation dynamics, illuminating interactions and linkages between different systems.

Further research should be dedicated to develop a digital tool facilitating integration of the innovation measurement framework in business management processes and systems, improving evidence-based decisions.

Appendix A: Survey Questions Considered as Variables

Business strategy
1.1. The company has strategic objectives associated with innovation?
1.2. The company has an annual plan of innovation activities?
1.3. The company applies management indicators associated with innovation?
1.4. The company applies other indicators or metrics that somehow contribute to understand and to assess the impact of innovation?
Activities and Innovation Projects
2.1. The company applies quantitative criteria, and other such criteria, when evaluating RDI projects, particularly associated with the demonstration of their potential impact and return on investment?
2.2. The company applies quantitative criteria, and other such criteria, when assessing, in addition to RDI projects, other innovation activities such as the idea-management process or knowledge-management process?
2.4. The company develops and applies some technologies and tools supporting the management of innovation activities?
Accounting
3.1. The company applies R&D cost accounting in analytic terms?
3.1.2. If so, can you identify the investments, costs, and profits associating these terms with projects?
3.2. The company applies cost accounting, in analytic terms, to other innovation activities, in addition to R&D?

Notes

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2. ROI (%) = ((Gain from investment—Cost from investment)/Cost from investment) $\times$ 100.

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CHAPTER 8

Smart Cities and the Quadruple Helix Innovation Systems Conceptual Framework: The Case of Portugal

Catarina Selada

8.1 Introduction

"Cities are considered key elements for the future" (Albino et al. 2015). They are hubs of innovation and growth, but they have also become the major contributors to the global problems the world is facing such as climate change, social exclusion and migrations.

Urban spaces around the globe concentrate economic, social and institutional resources, competing for the attraction of talent and investments. In 2013, 80 % of the world's global GDP was concentrated in cities, number that will grow to 85 % by 2050. Moreover, according to the MacKinsey Global Institute (2011), by 2025, the 600 biggest cities in the world are projected to account for 60 % of global GDP.

However, a rapid urbanisation process is taking place on a global scale. The UN report "World Population Prospects" projected a growth in world population of 2.3 billion between 2009 and 2050, from 6.8 billion to 9.1 billion, with all of this growth concentrated in urban areas. Cities represent around 70 % of global energy demand and 70 % of total energy-related

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carbon emissions. The energy and carbon footprint of urban areas will increase with urbanisation and the growing economic activity of citizens. Continuing the current energy system trends, urban primary energy demand will increase by 70 % between 2013 and 2050. In parallel, carbon emissions from energy use in cities will increase by 50 % (UN 2015).

Cities are a major part of the problem but they also have the potential to be part of the solution. For that, a new urban development model is needed as the response to the economic importance of cities, to the process of urbanisation, and to the demand for sustainable development and a post-carbon model.

This transition towards a new urban development model is reinforced by the opportunities offered by the digital revolution. The digitisation has "grown out of a rapidly advancing technological capability in terms of ICT infrastructure (including sensors), personal technologies (smart phones and use of internet, etc.), and data storage and processing capability" (Cosgrave et al. 2013).

Fixed and mobile internet, ubiquitous computing, social media and Web 2.0 applications, database design and systems of information management, distributed storage of data and new forms of data analytics are key elements of this digital revolution (Kitchin 2014).

According to Shadi et al.'s (2015) estimations, the number of internet users will grow from 2.9 billion to 4 billion by 2020. Smartphone usage will increase from 2 billion connections to 6 billion connections by 2020. Moreover, the global daily traffic is estimated to rise from 2 exabytes to 120 exabytes by 2020. And the number of connected devices will grow from 25 billion to 50 billion by 2020.

Data are viewed as an essential component to realising a smart city vision (Kitchin 2014). More data are being produced every two days at present than in all history prior to 2003. According to Rial (2013), 1.7 million bytes of data per minute are being generated globally. This hype of big data is "a transformation in the knowledge governance of cities through the creation of a data deluge that seeks to provide much more sophisticated, wider-scale, fine grained, real time understanding and control of urbanity" (Kitchin 2014), enacting new modes of governance, empowering citizens and stimulating economic growth and innovation.

"Smart cities" have been commonly referred as the answer to these challenges. This is a new paradigm on how to build cities, which requires new strategies, technologies, models and urban processes in order to meet the current challenges related to quality of life, environment protection and resource efficiency, equality and social inclusion.

In this chapter we will analyse the collaborative dynamics within the smart city field, namely the interaction among smart city actors in Portugal. We will test the validity of the application of the Quadruple Helix (QH) Innovation Systems Conceptual Framework to these dynamics, both theoretical and operationally.

In the first part we will present our vision about the smart city concept and domains, followed by the analysis of the interaction among smart city actors using the Quadruple Helix Innovation Systems Conceptual Framework and some international policy benchmarks. Then, we will analyse the case of Portugal with the presentation of the Smart Cities Portugal platform, and the collaborative dynamics among Portuguese smart city players. Some preliminary conclusions will be extracted.

8.2 Smart City Models and Approaches

8.2.1 Smart City Concept and Domains

There is not a universal concept of "smart city" shared among academics and policy-makers. However, smart cities are getting attention in the media, from technology companies and entrepreneurs, and from local governments and civil society (Cohen 2015).

The common denominator of smart city conceptions "seems to be access to data and intelligent tools to connect knowledge and people to drive change" (Copenhagen Cleantech Cluster 2012).

It is possible to define two extreme ideological visions about smart cities both in terms of policy and practice: a technology-driven and a people-centred approach.

Smart Cities Technology-Driven

In this vision, technology is the key component of smart cities. Global technology providers such as IBM, Cisco and Siemens are leading this movement characterised by technological determinism.

They are massively selling technologies to municipalities who do not have adequate capabilities to understand the impacts of these solutions on citizens' quality of life. Moreover, there is a risk of lock-in and path-dependency.

According to Hollands (2008) "a (…) element characterizing self-designated smart cities is their underlying emphasis on business-led urban development (…) there is a general world-wide recognition (…) of the domination of neo-liberal urban spaces, a subtle shift in urban governance in most western cities from managerial to entrepreneurial forms, and cities being shaped increasingly by big-business and/or corporations".

Masdar (United Arab Emirates), Songdo (South Korea) and King Abdullah (Saudi Arabia) are some well-known examples of top-down corporate-designed cities. The majority are newly built cities that make intensive use of ICT, eschewing "actual knowledge about how cities function and represent (ing) empty spaces that disregard the value of complexity, unplanned scenarios, and the mixed uses of urban spaces" (Albino et al. 2015).

French photographer Etienne Malapert spent ten days exploring Masdar city. His images captured the loneliness and emptiness of the city described by him as a "ghost town" (Wired 2016). Futuristic buildings, solar panels, wind towers, personal rapid transit systems, electric cars, smart technologies and shaded streets were not enough to attract people and build a sense of community.

Hollands (2008), Adam Greenfield (2013) and Anthony Townsend (2013) are some of the authors who have criticised these technology-driven urban visions, postulating that they forget the dynamism of how cities interact with their citizens.

Smart Cities People-Centred

Citizens and communities are the central actors in this vision. According to Hollands (2008), smart cities "must seriously start with people and the human capital side of the question, rather than blindly believing that IT itself automatically transform and improve cities". Due to the danger of technological determinism and urban gentrification, the author proposes a progressive concept of smart city.

In this approach technologies empower democracy, enhancing citizens' engagement and co-creation. Citizens are co-designers, co-creators and co-learners with government (Bollier 2016). "Successful smart cities of the future will combine the best aspects of technology infrastructure while making the most of the growing potential of 'collaborative technologies', and above all the citizens who power them" (Saunders and Baeck 2015).

Education, creativity, learning, sharing, collaborative economy and collective intelligence are characteristics of this approach much more centred on issues like equity and social inclusion.

Medellin (Colombia) is an example of community-led cities. From one of the most violent cities in the world to a case study of urban innovation, the city was elected as the Innovative Capital of the Year 2013 and won the Urban Transformation Global Award in 2016. Citizen engagement, co-creation and collaboration between government–academia–industry–civil society are key areas of the city's strategy "Medellin Smart City". For example, the co-creation platform MiMedellin.org encourages citizens' participation through open innovation methodologies, which is led by the City Council and a public entity called Ruta N.

Seoul and Amsterdam are leaders in the sharing society movement, addressing urban problems through sharing and citizens' engagement. Since the declaration of Seoul as a Sharing City in 2012, the city has been supporting several sharing organisations and businesses creating the institutional foundations for realising this ambition. Due to these efforts, Seoul was awarded (special mention) by Metropolis in 2014 as one of the world's sharing capitals.

According to Kitchin (2014), there is a "tension within smart cities between serving global mobile capital and stationary ordinary citizens; attracting and retaining an elite creative class and serving other classes; and top-down, corporatized, centralized development and bottom-up, grassroots, decentralized and diffused approach".

Between these two opposite visions, in our opinion technologies are enablers oriented to promote economic development and innovation, to assure sustainable growth, and to improve citizens' quality of life. We tend to agree with Caraglin et al. (2009) when they postulate "we believe a city to be smart when investments in human and social capital, and transport and ICT communications infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance". It is necessary a balance of power between the use of IT by business, government, communities and ordinary people (Hollands 2008).

Despite the necessary holistic view of a smart city, several authors have been separating the concept into several dimensions, facilitating the operational implementation of smart city solutions.

Some literature identifies only the hard domains associated to smart cities, such as energy, mobility, water management, waste management, logistics and so on, where ICT can play a decisive role in the function of the systems (Albino et al. 2015). This is the case of a vast amount of reports produced by multinationals. For example, IBM considers five city domains: water management, public safety, traffic, buildings and energy (IBM 2011).

However, soft domains should be considered, such as education, culture, governance, social inclusion and so on (Albino et al. 2015). In the same vein, management and organisations, technology, governance, policy context, people and communities, economy, built infrastructure and natural environment are the domains proposed by Chourabi et al. (2012).

We support the categorisation suggested by the report "Smart Cities: Ranking of European Medium-sized Cities", in which six characteristics of smart cities were presented: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living. Smart Economy comprises factors associated to economic competitiveness, such as innovation, entrepreneurship and internationalisation. In sequence, Smart People includes the level of qualification of the citizens, the quality of social interactions and openness. Political participation, the functioning of the administration and public services integrate the Smart Governance dimension. Smart Mobility refers to local and international accessibility, the availability of information and communication technologies and transport systems. Smart Environment includes aspects such as natural conditions, pollution, resource management and environmental protection. Finally, Smart Living includes quality of life (culture, safety, housing, tourism, etc.) (Vienna University of Technology et al. 2007).

However, in practice there aren't "one-size fits all" solutions. All cities differ in their historical, economic, social, cultural and institutional features. Lee and Hancock (2012) identified 143 smart city projects in the world in 2013. North America had 35 projects; Asia 50; Europe 47; South America 10; and the Middle East and Africa 10. Diversity and heterogeneity characterise this smart city movement in the world.

In fact, smart city initiatives have different motivations, promoters, governance structures, business models and financing sources. Alcatel Lucent (2012) analysis refers that there are three motivations behind smart city projects: the economic motivator, the eco-sustainability motivator and the social motivator, which are not exclusive from each other. The majority of the initiatives are promoted by governments (Birmingham Smart City), while others are led by private companies (Songdo Smart City in Korea). Partnerships (governments, academia and industry) are also common, being the example of "Smart Amsterdam" a well-known case study. In coherence, for some projects governments are responsible for the most important part of the funding, while in others private developers provide investments and capital.

8.2.2 Quadruple Helix Innovation Systems Conceptual Framework and Smart Cities

A city is not smart when it does not include all its stakeholders neither in the decision- and policy-making processes nor in the urban innovation processes. Smart city is based on knowledge sharing and collaboration across all levels of society.

This idea is conceptually linked to the Quadruple Helix Innovation Systems Conceptual Framework[1] (e.g., Liljemark 2004), a development of the Triple Helix Innovation Systems Conceptual Framework (Etzkowitz and Leydesdoff 2000). The Triple Helix Innovation Systems Conceptual Framework postulates a strong cooperation between academia (universities), industry (business) and state (government) in the knowledge production and innovation processes. It focuses on how innovative companies obtain support from state authorities, universities and R&D institutions. Government may be represented by any of the three levels as national, regional and local (Afonso et al. 2010).

The Quadruple Helix Innovation Systems Conceptual Framework introduces one additional actor in the innovation process—the civil society (and media and culture-based public). It can be described as "an innovation cooperation model or an innovation environment in which users, firms, universities, and public authorities cooperate to produce innovations (...) these innovations can be (...) technological, social, product, service, commercial or non-commercial innovations" (Arnkil et al. 2010). Moreover, innovation is now considered transdisciplinary, non-linear, hybrid, open and user-oriented (Chesbrough 2003; Von Hippel 1988).

In our approach, the Quadruple Helix Innovation Systems Conceptual Framework is spatially specific corresponding to a territorial (urban) innovation ecosystem, where cities take the leading role working closely with universities, industries and the civil society. The output is materialised in policy knowledge and innovative solutions oriented to solve urban problems and answer to the challenges cities are facing.

Establishing strategic vision, creating smart city strategies, defining regulation, providing public services, investing in networked infrastructure and making open data available are key roles of local governments. Companies are providers of products, services, platforms and urban solutions, or investors in smart city projects and programmes. They use urban spaces to test their smart city solutions in real-life environments. Universities and R&D centres develop fundamental and applied knowledge and partner with municipalities and industry in the conception and implementation of smart city projects. Technology transfer is another function of academic R&D centres. Finally, citizens demand for goods and services, co-create public services and urban solutions, enhance social capital, assure digital inclusion and develop civic initiatives.

These four actors have different objectives and priorities and potential conflicts of interests may emerge. Thus, it is necessary to break out the silos of knowledge through cross-sectoral collaboration towards a more integrated and holistic approach to city governance (Copenhagen Cleantech Cluster 2012).

From the QH perspective living labs could be considered to be an interesting innovation approach as they are related to the development of cities and regions. According to ENoLL—The European Network of Living Labs "living labs are defined as user-centered, open innovation ecosystems based on a systematic user co-creation approach integrating research and innovation processes in real-life communities and settings (...) living labs place the citizen at the center of innovation". "The aim is (...) harmonizing the innovation process among four main stakeholders: companies, users, public organizations and researchers" (Ståhlbröst and Holst 2012) (Table 8.1).

8.3 Smart City Actors and Collaborative Dynamics

8.3.1 Collaborative Platforms and Networks

Based on the referred theoretical models, and on the analysis of different international policy cases and practices, the collaboration among smart city actors within local, regional and national innovation ecosystems enhances the development of policy knowledge, urban data and information, and innovative urban solutions.

In this context, the creation of collaborative platforms and networks is an emerging phenomenon. Smart cities networks are integrated by several

Table 8.1 Smart city actors and roles

Actors	*Roles*
Governments	Establishing strategic vision and strategy, defining regulation, provision of public services, networked infrastructure investment, funding, new policy instruments, open data, solutions to societal challenges
Industry (companies, entrepreneurs)	Providers of smart solutions and platforms, know-how and investment
Universities and R&D Centres	Undertake R&D and supply technical products and services, knowledge transfer
Civil Society	Co-production of public services, building social capital, and assuring digital inclusion, society initiatives, demand for goods and services

municipalities and are being created in some countries, such as Spain (RECI—Spanish Smart Cities Network) and Brazil (Brazilian Human and Smart Cities Network). Cross-sectoral cooperation is a characteristic of local, regional and national platforms created to induce the collaboration among different smart city players. The Technology Platform "Smart Cities Austria", the "Smart Cities Mediterranean Cluster" and the "Tartu Smart City Lab" are some examples.

These platforms are very diverse in terms of conceptual background (labs, clusters, platforms, networks, associations, etc.), geographical level, key actors and intervention areas (Table 8.2).

8.3.2 Local Governments

Municipalities strive to deliver high-quality services for the benefit of citizens, so they are at the forefront of the smart city movement. However, to work in the area of smart cities they have to break down silos between departments and knowledge areas approaching cities holistically as complex systems. With this objective, smart city departments and Chief Information Officers are being integrated in governments' organisational structures.

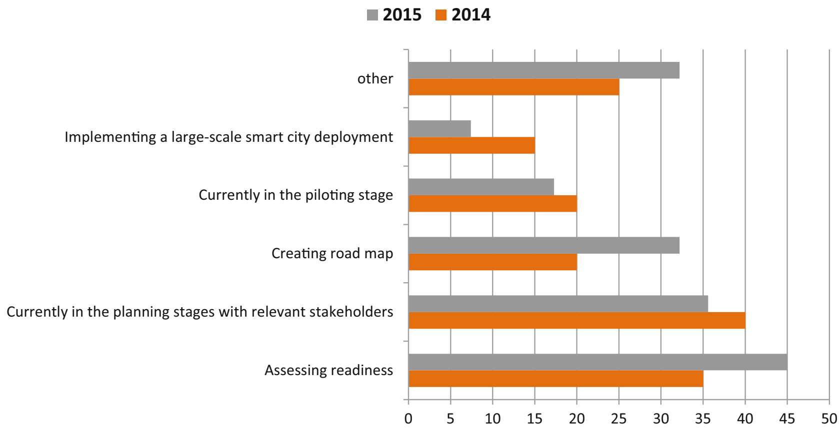
According to Robinson (2016), smart cities are an economic and political challenge, not a technology trend. Thus, political leaders have to be involved because "without them developments and investments in new technology and infrastructure will not create ubiquitously beneficial outcomes (...) historically, there is plenty of evidence that investments in

Table 8.2 Smart city platforms and networks

International platforms and networks	*Geographical level*	*Key actors*	*Intervention areas*
Smart City Lab—Cluster of smart e- and m-city solutions	Tartu, Estonia (local level)	Companies, citizens, public authorities, R&D institutes, innovation centres	Intelligent transports, networks and infrastructures, tourism, digital services, governance
Smart Cities—The Mediterranean Cluster	Mediterranean area (regional level)	Innovation centres, industry, civil society, other stakeholders	ICT, mobility, energy
Fondazione Cluster Smart Cities & Communities	Lombardi, Italy (regional level)	Companies, R&D sectors, other stakeholders	Energy efficiency and renewable energies, mobility, safety, health, e-government, education, tourism, cultural heritage
Cluster Andalusia Smart City	Andalusia, Spain (regional level)	Universities, sectoral associations	Smart society, technology, governance, energy, mobility
EMOCITY—Cluster for E-mobility and Smart City	Slovakia (national level)	Universities, R&D centres, municipalities, industry	ICT, mobility, energy, smart grids, R&D
Technology Platform Smart Cities Austria	Austria (national level)	Industry, cities, R&D centres, other stakeholders	Buildings, networks and infrastructures, energy, mobility
Smart Cities Association	India (national level)	Think tanks, businesses, public service providers, other institutions	Transportation, health care, energy, safety, home automation, water, telecommunications, utilities, data management, analytics

technology and infrastructure can create great harm if market forces alone are left to shape them”.

Data collection, analysis and integration are supporting evidence-based policy- and decision-making processes, improving urban efficiency and sustainability. For example, data are helping to predict floods, avoid water shortages and reduce water management costs by 15 % in the Netherlands. In India, real-time adaptive traffic control systems are resulting in a 12 % reduction in average traffic time (Shadi et al. 2015).



Graphic 8.1 Smart city initiatives in which municipalities are participating in (in %) (*Source*: Black and Veatch 2016)

Moreover, open data promotes citizens' engagement and stimulates the innovation process. "Open Data Barcelona" (hopendata.bcn.cat/opendata/es) and "NYC Open Data" (nycopendata.socrata.com/) are some well-known examples. In this framework, top-down actions co-exist with bottom-up initiatives, since governance and citizens can join together to co-create strategies, civic infrastructures, public spaces, transportation and so on.

Several governments around the world are creating smart city strategies and action plans in collaboration with stakeholders. The "Strategic Directions: Smart City Report" (Black and Veatch 2016) points out that the majority of smart city activities that are being developed by municipalities are centred on "assessing readiness", "planning stages with relevant stakeholders" and "creating roadmaps" (Graphic 8.1).

For example, Birmingham City Council published its "Smart City Vision Statement" (2013), which was followed by the production of "The Roadmap to a Smarter Birmingham" (2014). This roadmap sets out a "framework for the Birmingham's economic, community and third sector leaders, and Birmingham City Council, to come together and address the city's challenges of today—with the clear goal of building a more resilient and adaptable city for the future" (Birmingham Smart City Commission 2014).

The Roadmap has been developed by the Birmingham Smart City Commission, a body created by the City Council which includes key players from the business, academic and public sectors. "The role of the Commission is to provide thought leadership, set the standards for a smarter Birmingham and embed the core values of being visionary, open and collaborative, inclusive and people-centric across all city actions" (Birmingham Smart City Commission 2014).

Another interesting example is the "Smart City Wien—Framework Strategy" (2014), which is a long-term umbrella strategy to 2050 covering all areas of life, work and leisure activities, and including everything from infrastructure, energy and mobility to all aspects of urban development. The strategy was developed with strong stakeholders' involvement. In fact, the Smart City Wien Agency has organised several thematic forums attended by the city administration, business, science and civil society.

Local authorities have also to collaborate with national governments and European institutions in a perspective of multilevel governance.

Some countries are launching "Smart City National Plans". The Spanish government published its action plan in 2015 corresponding to a global budget of 152.9 million Euros (METI 2015). A Smart Cities Council was also created integrating ETSI, Re.es, IDEA, EOI, local entities and companies under the coordination of the Ministry of Industry, Energy and Tourism. Moreover, the Spanish Smart Cities Standardization Committee is developing specific technical norms in the area of smart cities.

National policies also have to create a favourable regulation framework for the implementation of smart city projects. For example, the UK launched the "Code of practice for testing of automated vehicle technologies" to provide guidance to anyone wishing to conduct testing of automated vehicle technologies on public roads or in other public places in the country (Department for Transport 2015).

After launching Europe 2020 strategy towards smart, sustainable and inclusive growth, the European Commission created the "Smart Cities and Communities European Innovation Partnership" (EIP). The initiative aims to accelerate the market uptake of smart city solutions integrating technologies from Energy, Transport and Information and Communication Technologies (ICT). The experimentation of these innovative solutions in real urban conditions with a view to their replication and full deployment in other European and worldwide cities is also a requisite of the initiative.

Under this framework, Horizon 2020 is financing large-scale lighthouse projects to be developed by partnerships between industry and local authorities under a "new cooperative working environment". "Public authorities need to act as a partner with industry, service providers, financiers, and end users to build the smart city" (Smart Cities Stakeholder Platform 2013).

Horizontal measures are also being supported in order to enhance market demand in the following domains: business models, standardisation, metrics, public procurement, regulations, stakeholders' engagement and so on.

8.3.3 Companies and Entrepreneurs

Smart cities offer a huge market opportunity to companies and entrepreneurs. This business sector comprises systems integrators, services providers, telecommunications companies, infrastructure suppliers, utilities, apps providers, construction companies and so on.

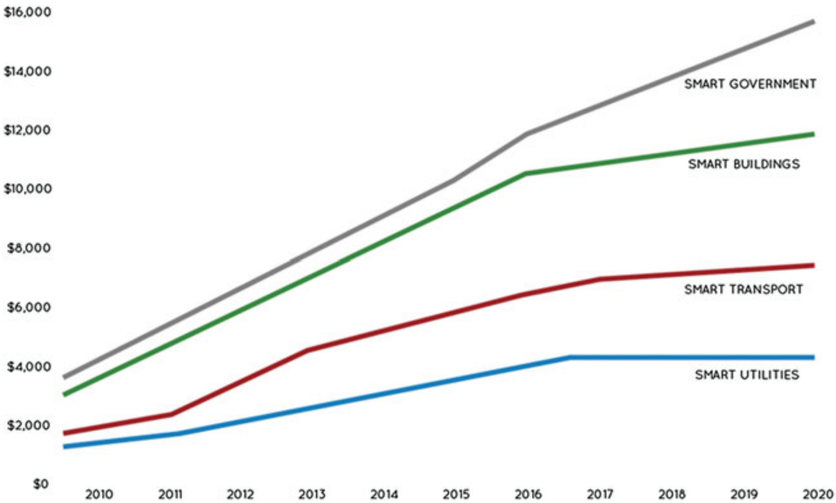
According to ABI Research Institute (2011), the market for technologies that feed into and support smart city programmes and projects is expected to grow on a global basis from 6.4 billion euros in 2010 to exceed 31 billion euros in 2016, accounting for 92 billion euros in cumulative spending during the period. Moreover, Pike Research estimates that the next ten years will see over $100 billion spent on technologies to support smart city development worldwide. By 2020, the annual spend on these core technologies will be almost $16 billion. Governance, buildings and mobility solutions are considered the main areas of growth (Pike Research 2011) (Graphic 8.2).

A report published by Arup in 2011 centred on the 36 members of the C40 network gives a good indication of the areas of focus in the implementation of smart city solutions. Smart energy metering, smart transport cards, electric vehicles and real-time transport information are the solutions with a higher level of implementation (Graphic 8.3).

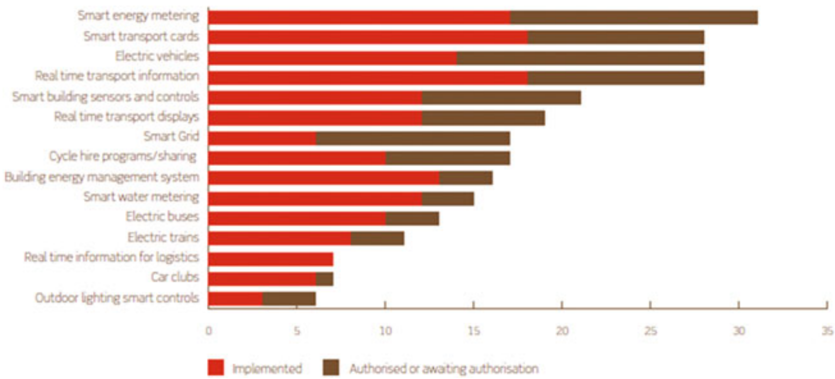
Several national governments are aware of this opportunity with a view to promote competitiveness, create new jobs and enhance internationalisation.

For example, the study "The Smart City Market: Opportunities for the UK" (DBIS 2013) identifies global market opportunities for the UK industry in smart city technology, exploring its market structure and size. In July 2014, a similar document was launched by Arup and Future Cities Catapult describing UK capabilities for urban innovation and documenting the wide range of UK industry, research and civic capabilities relevant for driving innovation for the world's future cities. The report recognises that "companies, researchers and institutions that can provide the innovations that solve complex city problems will enjoy a sizeable and growing market for their skills, products and services" (Arup 2014).

Future Cities Catapult, one of nine Catapults established by Innovate UK, the UK Government's innovation agency, is oriented to strengthen the



Graphic 8.2 Smart city and smart infrastructure investment by industry, World Markets, 2010–2020 (*Source*: Pike Research 2011— $million)



Graphic 8.3 Smart city solutions in 36 member cities of the C40 network (*Source*: Arup 2011)

UK's ability to turn urban innovations into commercial reality. It provides world-class facilities and expertise to support the development of new products and services, as well as opportunities to collaborate with others, test ideas and develop business models. The Catapult helps "innovators turn ingenious ideas into working prototypes that can be tested in real urban settings (…) then, once they're proven, (it) helps spread them to cities across the world to improve quality of life, strengthen economies and protect the environment" (futurecities.catapult.org.uk).

The report "Danish Smart Cities: Sustainable Living in an Urban World" published by the Copenhagen Cleantech Cluster (2012) provides an overview of Danish smart city competencies and strengths, and some general recommendations to foreign companies and stakeholders who wish to enter the Danish smart city market. A list of smart city companies working in Denmark is also delivered. According to this document "we expect significant growth within the smart city market and a big part of this growth will be activated through the use of data and data management".

Large companies such as IBM, Cisco and Microsoft are strongly involved in the smart city market providing smart solutions and platforms, know-how and investment. The technological component is the key factor of their conceptions of smart cities. These technology providers are partnering with cities in the implementation of smart city projects. For example, the Spanish company Indra is collaborating with the Municipality of Coruña within the "Coruña Smart City" project, implementing an urban management platform which integrates all the city's smart services and solutions in the domains of environment, energy, mobility, safety, tourism and e-government.

Entrepreneurs and start-ups are also developing smart solutions and applications oriented to solve urban problems and answer to city's future challenges, using open data systems. These micro-businesses are being supported by public and private initiatives such as apps contests, hackatons, incubators, co-working spaces, funding programmes and so on. Lisbon is considered one of the best cities for entrepreneurs and start-ups, providing a network of incubators, creative spaces, fab labs and so on that constitutes a powerful innovation ecosystem. In the same vein, Amsterdam was elected the European Capital of Innovation 2016 (iCapital) for embracing a bottom-up approach based on smart growth, start-ups, livability and digital social innovation.

8.3.4 Universities and R&D Centres

Universities and knowledge centres are also involved in the smart city movement, working within research areas relevant to smart cities.

Besides capabilities across business, the referred reports "Danish Smart Cities: Sustainable Living in an Urban World" (Copenhagen Cleantech Cluster 2012) and "Future Cities: UK Capabilities for Urban Innovation" (Arup 2014) provide a list of universities and knowledge institutions developing research in the smart city domain in order to structure national research capabilities.

Several universities are creating urban-focused multidisciplinary research centres, recognising that working beyond single disciplines is the only way to approach smart city research. Moreover, universities are collaborating with other partners to apply research in real-world contexts and for demonstrating and testing urban innovations. One relevant example of collaboration between cities and universities in smart city projects is the MetroLab Network (metrolab.heinz.cmu.edu/). This initiative is aimed at improving American cities through university-city partnerships. It is part of a programme financed by the USA government to boost creative collaborations, new technology and solid data.

Under this scope, urban science centres are emerging in universities around the world, being urban science defined "as an emerging domain of research at the intersection of science and design, drawing on new disciplines in the natural and informational sciences, that seeks to exploit the growing abundance of computation and data" (Townsend 2015a). According to the author, by 2030 $2.5 billion will be invested in urban science and informatics research (Fig. 8.1).

New organisations are outpacing traditional ones. The "Centre for Urban Science and Progress" (New York University) and the "Amsterdam

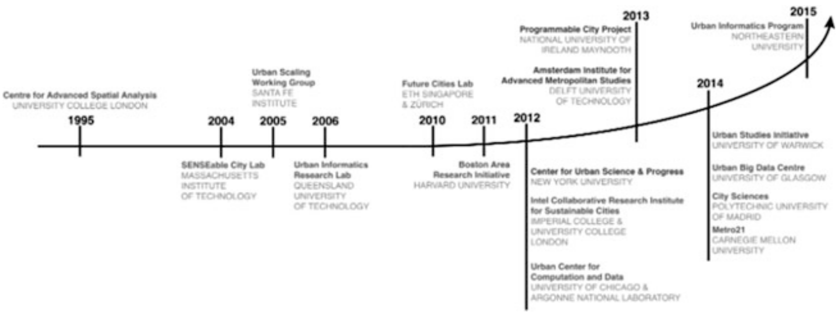


Fig. 8.1 Timeline of urban science institutions (*Source*: Townsend 2015b)

Institute for Advanced Metropolitan Solutions" are recent and well-known initiatives. CUSP is focused on the collection, integration and analysis of data to understand and improve urban systems and quality of life, using New York City as a living lab. Its anchor project is the Urban Observatory which intends to analyse the huge amount of data in cities and develop new scientific instruments to collect novel urban data.

The Amsterdam's institute resulted from the collaboration between the Delft University of Technology, Wageningen University and MIT's Centre for Advanced Urbanism. It was the winning proposal of a call launched by the Municipality to create a new applied technology research institute. In the institute "science, education, government, business partners and societal organizations are working tightly together to create solutions for the complex challenges a metropolitan region like Amsterdam is facing now and in the future" (www.ams-institute.org).

In the education field, several smart city masters and doctorates courses are being launched by universities. UCL is developing a Master of Smart Cities and Urban Analytics and CUSP grants a Masters in Applied Urban Science and Informatics.

8.3.5 Civil Society

Citizens are key actors in smart city planning and implementation. Civil society should be involved in the policy- and decision-making process, in the urban innovation process and in the collection and analysis of urban data and information. "Open data invites cross-sector, trans-departmental participation and cooperation (...) it allows citizens to engage more seriously with city government, not just offering comments and critiques, but in providing their own data and innovative ideas" (Bollier 2016).

Fix my Street platform (UK) was one of the first initiatives designed to promote the participation of citizens in reporting and discussing local problems (like graffiti, broken paving slabs or street lighting). Change by us (New York) invites citizens to propose ideas to make the city a greener and greater place to live. Starting with the Amstel 3D Pilot, Amstel3City is a smart city initiative for real-time master planning in implementation within the Smart City Amsterdam programme. It is an online urban transformation dashboard, which integrates visual storytelling, data-sharing, co-creation, participatory democracy, crowdsourcing and crowdfunding. Citizens, businesses, knowledge centres and the government "can exchange information and ideas and collectively plan, make and own their city or neighborhood" (amsterdamsmartcity.com/).

The involvement of users in the urban innovation process can be illustrated by the RIO+ initiative launched by the social company Benfeitoria. It is a collaborative creative platform oriented to collect ideas to the city's problems proposed by the community. The solutions are selected through online public voting and are implemented in the urban space with the support from the City Council (riomais.benfeitoria.com/).

Smart society initiatives are also emerging from the ground, often using low cost and publicly available ICT platforms and solutions. Urban action forums, social network platforms, social innovation incubators, carpooling networks and volunteering networks are some recognised examples (Ovum 2011).

Finally, citizens are increasingly involved in the collection of data and information, namely related to environmental issues such as carbon emissions, energy consumption and air quality. These initiatives contribute to accelerate the adoption of technologies by the society, and provide knowledge to the decision-making processes. For example, the Amsterdam Smart Citizens Lab promoted by the City and Waag Society stimulates citizens to collect and analyse data and information through smartphones, smart watches, Do-it-Yourself sensors and so on. A Smart Citizens Kit, an open source device that monitors the environment was experimented, which helped people to understand the possibilities of citizen science.

The sharing economy is also a trend that contributes to the improvement of collaboration within communities. It includes the "shared creation, production, distribution, trade and consumption of goods and services by different people and organizations" (Matofska 2016). Car-sharing, bike-sharing, co-housing and co-working spaces are some examples of this phenomenon. The sharing economy is strongly linked to smart cities, since cities are increasingly supporting the sharing movement. Amsterdam, Milan and Seoul are world-class case studies.

8.4 Case-Study: Smart Cities Platform in Portugal

8.4.1 Overview

In Portugal there is no national strategy towards smart cities. However, recent policy documents make reference to living labs and smart cities. "Portuguese Reform Program" and "Startup Portugal" are relevant examples. Regional authorities (CCDR—Regional Coordination and Development Commissions) do not have political legitimacy, but they are the entities responsible for managing "Regional Operational Programs".

Local dynamics are leading the smart city movement in Portugal. Several cities are defining strategies, policy tools and collaborative approaches to deal with this ambition. Global technology providers are trying to sell their products to municipalities, and start-ups and urban entrepreneurs are increasingly emerging. Universities and R&D centres are wakening for the phenomenon, recognising the need to multidisciplinarity in smart city research. Finally, the involvement of citizens and communities in the urban innovation and policy-making process is still in infancy. However, some grassroots and civic movements are arising.

Informal cooperation networks are being formed, namely the Portuguese Smart Cities Network (RENER) and the Smart Cities Portugal platform. The former aggregates several municipalities who want to develop and implement smart city strategies, and the last one intends to become a collaborative platform integrated by cities, companies, universities and R&D centres, and users. The aim of these initiatives is to promote partnerships within and among the four helices of the Quadruple Helix Innovation Systems Conceptual Framework.

8.4.2 Smart Cities Portugal Platform

Smart Cities Portugal is a collaborative platform integrated by companies, R&D centres, universities, technology infrastructures, associations and municipalities, founded in 2013. At the moment 50 organisations are part of the network. It intends to create synergies among the different players operating in the smart city market, enhancing the roll-out of integrated and scalable creative solutions to solve urban problems.

The platform aims at positioning Portugal as a developer and provider of technologies, products and high value-added systems for smart cities at global level, promoting companies' competitiveness, innovation capabilities and internationalisation. The country could be considered as a living laboratory for the development and testing of innovative urban solutions in real-life context, attracting foreign direct investment. In fact, smart city solutions tested in Portuguese cities can be replicated in other urban spaces around the world.

The Smart Cities Platform intends to act as an intelligence, advocacy, awareness and accelerator alliance, contributing to a better understanding of the smart city sector in Portugal in order to support decision- and policy-making processes.

The general objectives of this initiative are:

- Promote the development of smart city pilot projects in cooperation among cities, R&D centres and companies, with a view to improving citizens' quality of life;
- Stimulate the scaling up of innovative urban solutions, replicating worldwide the smart city projects tested in Portuguese cities;
- Promote the participation of Portuguese players in lighthouse European projects in the area of smart cities;
- Promote the internationalisation of Portuguese companies working in the smart city market;
- Enhance the creation of new companies in the smart city market, supporting urban entrepreneurship;
- Evaluate the impact of smart city projects on wealth creation, jobs generation, environment quality and citizens' quality of life, through the use of specific metrics and key performance indicators;
- Contribute to increase the local content of foreign direct investment projects linked to smart growth;
- Increase the participation of Portuguese cities and companies in international territorial, knowledge and commercial networks.

Internationalisation, R&D and innovation, entrepreneurship, funding and regulation are the strategic areas of intervention of the Smart Cities Portugal platform, centred on the following domains: energy, mobility, environment, economy, governance and quality of life.

Internationalisation Creating favourable conditions to promote the internationalisation of Portuguese companies operating in the smart city market. The cooperation between companies oriented to the development of integrated solutions across energy, mobility, ICT and so on enhances their participation in global value chains. Intelligence exercises will help the identification of business opportunities and collaboration possibilities related to smart city projects.

R&D and Innovation Stimulating the development of integrated, innovative and sustainable solutions for smart cities, using the competencies of universities, R&D centres and technology infrastructures. Providing information and knowledge about smart cities to companies' employees and municipal staff is also important, in areas such as business models, financial mechanisms, partnerships, case studies and so on.

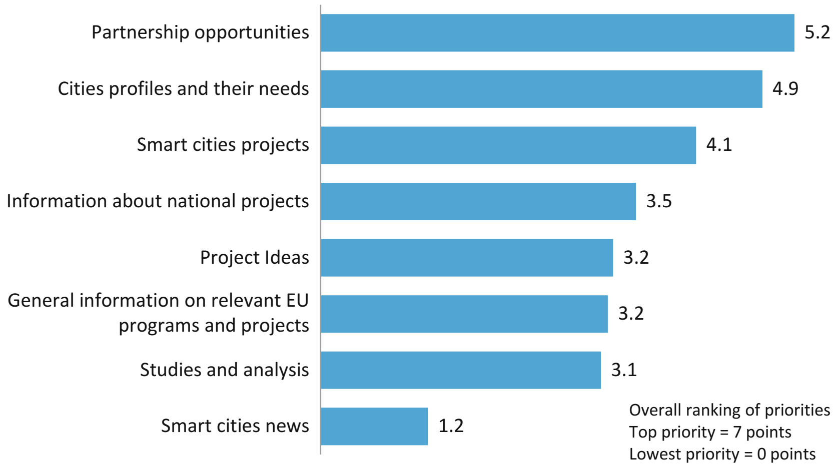
Entrepreneurship Promoting urban entrepreneurship, supporting the development of innovative ideas, applications and solutions oriented to answer to the challenges cities are facing, in the areas of mobility, energy, governance, tourism, health and so on. Launching start-ups in these areas enhances wealth growth and job creation, contributing simultaneously for solving urban problems. Open data, apps contests and incubator spaces facilitate entrepreneurship and the creation of new businesses.

Funding Creating favourable conditions to facilitate the access to funding by companies, municipalities and R&D centres, namely within the European programming period 2014–2020. The "Smart Cities and Communities European Innovation Partnership" (EIP) is coordinating smart city research and innovation projects, which could be supported by Horizon 2020, COSME, LIFE + and Cohesion funds. The cooperation between cities and industry is an added-value when applying for lighthouse smart city projects.

Regulation Participating in international forums on smart city standardisation and normalisation, and contributing to the elimination of legislation barriers to the development and implementation of smart city projects. The provision of interoperable systems is one of the most important issues in this debate. ISO—International Organisation for Standardisation, CEN—European Committee for Standardisation, City Protocol Society, and specific national organisms are already working in this field.

Under the framework of the Smart Cities Portugal platform, a study has been developed in order to identify and analyse smart city business and research capabilities in Portugal—"Smart Cities Portugal Roadmap" (INTELI 2014).

Hundred entities (companies and R&D organisations) were inquired; 78 % of these organisations consider "very important" and 22 %



Graphic 8.4 Access to information needs of smart city companies (*Source*: INTELI 2014)

"important" the launching of this platform. None of them referred the network as "non-important" or "irrelevant".

Around 60 % consider "difficult" or "very difficult" the access to information about the smart city market. Information about partnership opportunities and cities' profiles and needs are the priorities identified by companies (Graphic 8.4).

However, in the opinion of the inquired entities the identification of business opportunities is the most relevant advantage of participating in the Smart Cities Portugal initiative.

8.4.3 Local Governments

Local authorities are the leaders in the development of the smart city movement in Portugal. Some of them are starting with the definition and implementation of a strategic framework to guide major urban development projects; others are developing specific, distributed interventions in buildings, open data or mobility, before trying to connect these dimensions (Arup 2010). However, the majority of the municipalities lack integrated strategies and roadmaps.

Some good practices that are being developed by national cities were awarded with the "Smart Project for Smart Cities" Label, promoted by INTELI. The bike-sharing system of Torres Vedras, the intelligent public lighting system of Águeda, the environmental information system of Matosinhos, the digital urbanism platform of Vila Nova de Gaia, and the smart waste management system of Cascais were some of the distinguished projects in 2015.

Bigger cities such as Lisbon and Oporto are integrated in European consortiums in the area of smart cities. Oporto is follower city in the "Grow Smarter" lighthouse project. Lisbon is partnering with London, Milan and other stakeholders in the "Sharing Cities" project, supported by Horizon 2020—"Smart Cities and Communities". The objective is to integrate and demonstrate smart city solutions crossing energy, mobility and ICT in urban districts. Within this project, Lisbon will launch an Integrated Operations Centre with the aim of collecting, analysing and integrating real-time data and information about cities' services and operations to support decision-making processes. "Lisboa Aberta" (Open Lisboa) is the city's open data portal, one of the first initiatives in Portugal in this area.

However, cities are represented in the Smart Cities platform through RENER—Portuguese Smart Cities Network, and not in an isolated manner.

RENER was created under the Portuguese Electric Mobility Program, as a pilot network for the introduction of the electric vehicle in the country. Several charging points and other related technologies were tested in these urban spaces by large international manufacturers such as Renault, Nissan, Mitsubishi and Peugeot. National technology solutions are being exported to the USA, Asia and several European countries. In 2013, RENER extended its intervention field integrating other urban domains, such as energy, buildings, environment, governance, social innovation and so on.

At the moment, RENER is composed of 46 municipalities, representing 45 % of national population and 19 % of the territory. It is a space for development, testing and experimentation of smart urban solutions in real-world context, under the concepts of open innovation and co-creation with the involvement of end users. It is also a space for sharing best practices and innovative experiences capable of replication, as well as for the incubation of local solutions with potential for internationalisation. Managed by INTELI, RENER is a member of ENoLL—The European Network of Living Labs.

Several join projects are emerging within the network due to the work of the municipalities in five thematic groups: governance; energy and environment; mobility; society and quality of life; economy and innovation. Cities offer their territories to companies and entrepreneurs who want to test, experiment and validate smart solutions in real-life context.

In 2013, RENER established a cooperation agreement with RECI—Spanish Smart Cities Network, composed of around 70 municipalities. Some projects have been developed in partnership, such as Startup4cities Iberia in the area of urban entrepreneurship. Several contacts are also being established with Brazilian cities and institutions.

8.4.4 Companies and Entrepreneurs

The referred "Smart Cities Portugal Roadmap" (INTELI 2014) has identified the characteristics of the smart city industry in Portugal.

Among the companies inquired 75 % are classified as small- and medium-sized enterprises. Only 14 % have a share of foreign capital in their equity capital, and have decision centres located outside the country.

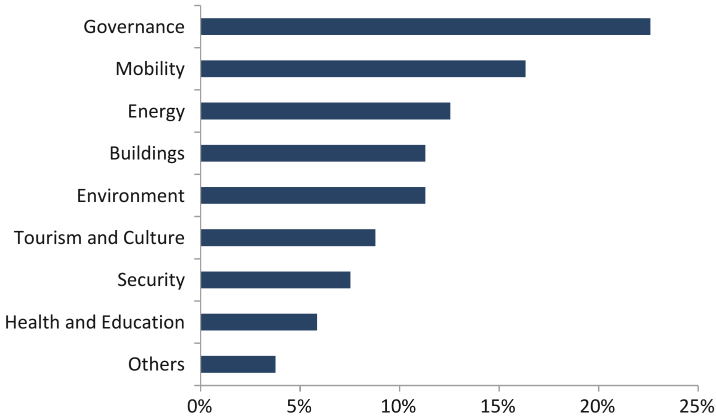
The Lisbon and Oporto Metropolitan Areas are the main locations of these organisations, followed by the municipalities of Coimbra, Aveiro and Braga/ Guimarães where well-known universities are sited. The agglomeration effect in the coastal area is also a reality.

Among the respondents, 35 % have already created organisational departments to deal with smart city issues, demonstrating the importance that these entities are giving to this new market.

Of the total human resources working in these companies, 70 % have graduate and 1 % PhD levels of qualification. The high level of graduates in the workforce reveals a knowledge and technology-intensive smart city sector. Moreover, R&D investment corresponds to 13 % of global turnover, which is a significant amount compared to the average Portuguese companies' R&D investment.

According to the information available, governance, mobility and energy, followed by buildings and environment are the areas in which these companies are developing smart city solutions (Graphic 8.5).

E-government solutions, municipal portals, management systems (ERP, AIRC) and public procurement tools are the principal products and services provided in the governance area. Mobility products and services are mainly linked to electric mobility (charging points, electric bike-sharing, electric car-sharing), parking management and integrated ticketing. Intelligent



Graphic 8.5 Smart city solutions developed by Portuguese companies (*Source*: INTELI 2014)

lighting systems, PV panels and integration of renewable energy solutions are some of the products offered in the energy area. There were also identified some solutions in the field of waste management, such as intelligent containers, contributing to cost reduction and efficiency gains in cities. Systems integrators, mainly multinationals are developing smart city platforms, with the aim of providing real-time information to services' operators and local authorities.

Twenty-seven per cent of the respondents have registered patents related to smart city products, which is a relevant number compared to the Portuguese average.

Twenty-eight per cent of the companies exports smart city products and solutions. Their markets are mainly located in Europe (Spain, France, Turkey, Switzerland and Ireland), Africa (Angola, Mozambique) and Latin America (Brazil). Moreover, 10 % of the smart city turnover is exported, with a specific emphasis in the areas of energy and mobility. It is worthy of notice that when companies were asked about their future target markets, the scenario is slightly different, due to the growing opportunities identified in Latin America and also in Asia and Middle East.

Smart city market is not yet in a mature stage of development. To accelerate the transition towards a renovated urban development paradigm, it will be needed to strengthen enablers and removing market barriers. Overcoming these barriers will enhance the adoption of innovations, the deployment of smart city solutions and the enlargement of the market. The perception of respondents resulted in the systematisation of the following barriers:

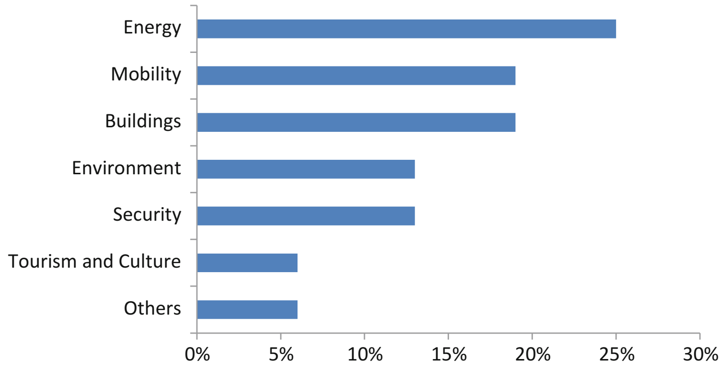
- Lack of integrated and coherent public policies;
- Weak culture of urban planning and city management;
- Resistance to change and innovation by local authorities;
- Lack of coordination between departments, infrastructures and urban functions;
- Ambiguity and vagueness of the smart city concept;
- Fragmented vision of what is a smart city;
- Lack of information and knowledge related to the smart city market;
- Absence of demonstration projects to show the benefits of smart city solutions;
- Market with a high diversity and heterogeneity of players;
- Domination of global companies in the smart city market;
- Lack of integrated solutions and competencies;
- Difficulty in launching interfirm and interinstitutional cooperation processes;
- Absence of standards and interoperability;
- Problems with legislation and regulation;
- Economic crisis and lack of funding sources.

Twenty-nine per cent of the respondents have already participated in large-scale smart city projects, with a great relevance of mobility and energy as application areas. These projects were mainly funded by national and European programmes, such as 7th Framework Programme, Competitiveness and Innovation Framework Programme and Horizon 2020.

8.4.5 Universities and R&D Centres

Beyond the traditional urban studies, Portuguese universities and knowledge organisations are increasingly involved in smart city research. Energy, mobility and buildings are their main areas of intervention (INTELI 2014) (Graphic 8.6).

However, universities are recognising the need to cooperate with cities in the development of R&D and demonstration projects. For example, the University of Minho launched the “UMCidades” (UMCities) initiative. It intends to fill the gap between knowledge and policy in the field of urban



Graphic 8.6 Smart city areas in universities and R&D centres (*Source*: INTELI 2014)

studies. Improving the debate among knowledge organisations and policy-makers is also an objective of "UMCidades". One of its anchor projects is the "City of the Year" award, which aims to distinguish good practices and projects under development by Portuguese municipalities.

Moreover, universities are becoming aware of the need to break down the silos of knowledge. A multidisciplinary methodology is needed to approach the smart city research field. The University of Oporto—Faculty of Engineering launched the "Centro de Competências para as Cidades do Futuro" (Centre of Competencies on Future Cities). "It is focused on bringing together, developing and applying knowledge, skills and competences of multidisciplinary nature in order to promote economic development and social inclusion in urban environments". The centre concentrates the expertise of University of Oporto in areas such as communication technologies, services, models and instruments of intervention to the urban and metropolitan scales, simulation, construction, operation and management of environmentally sustainable cities.

They want "to turn Porto into a smart city, a living lab, by providing it with a wide range of sensors and communication equipment, thus creating the conditions for future research and development using advanced technologies for data collection through mobile platforms, wireless communication and large-scale information processing" (futurecities.up.pt/site/build-research-capacity/).

Moreover, some masters and training courses are being launched in the area of smart cities. The Nova University of Lisbon is beginning a postgraduate programme in smart cities which "is aimed at managers, technical staff in public or private sectors, and other professionals that wish to acquire skills and knowledge in information systems for smart cities, using the most advanced technologies, data collection, analysis, and processing methods" (www.novaims.unl.pt/sc).

These initiatives are recent but have a great potential for replication in other universities and R&D centres.

8.4.6 Civil Society

Civil society is not formally represented in the Smart Cities Portugal platform. The same happens with arts, media and culture organisations, considered also as the "fourth helix" in some authors' approaches to the Quadruple Helix Innovation Systems Conceptual Framework.

However, some municipalities are trying to involve citizens in the policy and decision-making processes. Several Portuguese cities are using participatory budgeting as a policy tool, in which ordinary people decide how to allocate parts of municipal budgets. There are reported 158 on-going experiences of participatory budgeting in Portugal (www.portugalparticipa.pt).

Methodologies similar to UK "Fix my Street" are being implemented by a small number of local governments. Fix Cascais (Cascais), AlertaTVedras (Torres Vedras) and "A Minha Rua" (My Street) (Lisbon) are some examples. Crowdsourcing platforms are not generalised, and initiatives related to collective data collection and analysis were not identified.

One case study is the on-going initiative "Desafios Porto" (Oporto Challenges), a project that allows the public to contribute actively to the resolution of the problems that the city lives every day by presenting challenges. In order to participate citizens have only to identify a challenge experienced by the city of Oporto in one of the four categories—Health and Wellness; Energy; Digital City; Mobility and Environment. Sixteen challenges were selected through public voting and local entrepreneurs and companies have been called to propose technological and innovative solutions to solve these challenges. At the end the elected solutions will be implemented in the city of Oporto with the support from the Municipality and some sponsors.

In Aveiro several civic movements are emerging. VivaCidade Aveiro, Vivó Bairro and Ciclaveiro are some relevant examples. VivaCidade aims at identifying and intervening in "empty spaces" in the city, acting the citizens as actors of urban change. Vivó Bairro intends to promote the sense of community in historic neighbourhoods through the organisation of several join activities (urban art, civic workshops, etc.). Finally, Ciclaveiro is coordinated by a group of citizens who want to promote the use of bicycle as an alternative transport mode.

8.4.7 Collaborative Dynamics

The smart city sector in Portugal is still in an emergent stage of development. Besides the creation of informal platforms and networks, there is a need to increase the collaborative dynamics within and among the different helices of the Quadruple Helix Innovation Systems Conceptual Framework: local authorities, companies, universities and the civil society.

Since the 1980s, industry-university partnerships have been promoted within the national innovation policy. Specific policy instruments used for achieving this objective were science and technology parks, technological infrastructures, incubators and join projects funded by European, national and regional sources. Since 2007, these partnerships are also being supported by international programmes established between Portuguese universities and the Massachusetts Institute of Technology, Carnegie-Mellon University, University of Texas at Austin and the Fraunhofer-Gesellschaft.

City-industry collaboration is essentially focused on traditional commercial relationships, being necessary a "new cooperative working environment". Pre-commercial public procurement of innovation, green public procurement, tax incentives and specific regulations are some of the policy tools that can be used to facilitate this interaction. These partnerships are being enhanced by European lighthouse projects in the area of smart cities and communities. In this process, cities are offering their territories as living labs for companies who want to test innovative technologies and solutions in real-life environments.

Moreover, Portuguese companies are facing several market barriers when they approach the smart city market, namely the vagueness of the concept, the lack of information, the absence of standards and the dominance of global technology providers. This market has specific characteristics when compared to other traditional commodities markets. New governance models, new business models and new funding schemes are needed.

Municipality–university relationships are more recent. Universities are looking for a "new" role in society beyond education and research. They want to improve their connections within the urban innovation ecosystem, contributing for solving city's problems. Due to the reinvention of "urban science", several research centres are being created within universities in order to promote interdisciplinary smart city research. Data management and analytics are disciplines that are being applied for collecting and integrating urban data and for studying urban metabolism. Moreover, knowledge centres are also using cities for testing and validating their ideas and conceptions.

Citizens are the "silent actors" in this collaborative dynamics. Besides some isolated examples, the majority of the cooperation projects do not integrate the user side. The adoption of technologies is harmed by the lack of user involvement in the innovation process. And the lack of community participation in solving urban problems induces the application of technologies not compatible with people's needs.

This situation reveals the dominance of an embryonic Triple Helix Innovation Systems Conceptual Framework. Collaboration among municipalities, companies and universities is increasing but it is not in mature stage of development. However, some isolated national and local projects are being or were developed according to the Quadruple Helix Innovation Systems Conceptual Framework, such as "Future Cities" initiative (2011–2015).

8.5 Conclusions

Smart cities are emerging as a new urban development model, responding to the economic importance of cities, to the process of urbanisation and to the demand for a post-carbon model. Besides the diversity of the phenomenon, a smart city is a territory where the investments in human and social capital, and ICT infrastructures and networks promote economic development, environmental sustainability and a high quality of life, through participatory governance.

A city is not smart when it does not include all its stakeholders in the urban innovation process. Smart city is based on knowledge sharing and collaboration across all levels of society.

In this framework, the creation of collaborative platforms and networks is an emerging phenomenon in the smart city arena. Promoting the interaction among the four helices of the Quadruple Helix Innovation Systems Conceptual Framework, municipalities, companies, universities and the civil society is the aim of these initiatives. QH is considered an urban innovation environment oriented to the co-creation of creative solutions to solve urban problems and to answer to the city's future challenges.

In Portugal, the smart city context is characterised by an embryonic Triple Helix Innovation Systems Conceptual Framework, besides the existence of some informal platforms like RENER—Portuguese Smart Cities Network and Smart Cities Portugal platform. To increase the collaboration between smart city actors and to include the civil society in the urban innovation process are needed to build an attractive, sustainable and inclusive innovation ecosystem.

Future research will be dedicated to the quantitative analysis of the smart city actors' collaboration.

Note

1. This approach is theoretically linked to the interactive model of innovation (Kline and Rosenberg 1986), Mode 3 of knowledge production model (Gibbons et al. 1994), national innovation systems theory (Lundvall 1988; Nelson 1993) and clusters thinking (Porter 1990).

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CHAPTER 9

Open Innovation Adoption in Clusters: The Portuguese Case

António Bob Santos and Sandro Mendonça

9.1 Introduction

Innovation is a plural phenomenon, but also a structured process. Context matters. Etzkowitz and Leydesdorff (2000) proposed a view on the relationship between "University–Business–Government" to explain the structural development of knowledge-based economies and the process of innovation. In these "triple" interactions are assumed that there is a helix configuration, asserting the existence of spiral connections that promote knowledge and innovation, with institutional boundaries being blurred between public and private entities, between science and technology, and between university and industry (Leydesdorff 2000).

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Recent studies extend the concept of Triple Helix (TH) by introducing other actors in the model—for example, citizens and social networks—leading to the emergence of the concept of quadruple helix, quintuple helix or n-helix (see Leydesdorff 2012.). Santonen et al. (2008), based on the open innovation concept (Chesbrough and Bogers 2014) stress the importance of distributed social networks and citizen participation in the innovation process, taking advantage of the potential of the Internet and digital technologies, which in turn change the traditional relationship between "Universities–Business–Government", thereby engaging with innovation as a pervasive trend in twenty-first-century societies.

In the initial model of TH, increasing interaction and cooperation between "University–Business–Government" led to the development of new strategies and innovative practices, constituting this TH as a platform for the emergence of new institutional settings, with new organizational formats to promote innovation, such as incubators, science parks and technology, venture capital companies and so on. These new collective dynamics formats provide working syntheses of the interaction between "University–Business–Government" (Etzkowitz 2003).

These new institutional configurations have the common goal of creating an environment for open innovation, stimulating the emergence of university spin-offs, trilateral development strategies, the creation of strategic alliances between companies, research centers and laboratories and other public bodies and private. These interactions and institutions are often encouraged (but not controlled) by the government (Etzkowitz and Leydesdorff 2000), and may take the configuration of a cluster.

Research relating open innovation and clusters is still scarce, although there are already persuasive accounts of open organizational and interorganizational networks that may be seen as part of the clusters approach (Buchmann and Pyka 2015; Jarvenpaa and Wernick 2011; Malecki 2011; West and Bogers 2014; Simard and West 2006). Clusters are also "ecosystems" favorable to the innovation process and to open innovation activities, although the effects depend on the type of sector, the stage of development and the characteristics of firms and actors of each cluster (Uyarra and Ram Logan 2012).

Terstriep and Lüthje (2011) mentioned that the cluster definition of Porter (1998, p. 78)—"*geographic concentrations of interconnected companies and institutions*"—constitutes an important context for open innovation activities. Themes such as international networks (and networks in general), collaboration between companies or between companies and other entities (important practices in open innovation literature) are regular routines in clusters. Also Halbert (2010) reinforces this issue, concluding that organization in cluster can stimulate open innovation, contributing to the creation and searching for partnerships between different actors. Thus, by their nature, clusters appear to be favorable ecosystems to analyze open innovation practices in the real world, especially what concerns to areas that influence firms in the adoption of open innovation practices.

Given the lack of academic research linking clusters and open innovation, this chapter attempts to analyze the determinants for the adoption of open innovation in clusters, based on the Portuguese case.[1] This analysis also intends to understand how open innovation can help to improve the dynamics of clusters (and vice versa) and enhance innovation dynamics in Portugal. To this, we built and launched a survey to all members of the clusters recognized by the Portuguese Government.[2]

The chapter is structured as follows. We discuss the methodological considerations about the survey (Sect. 9.2). The chapter continues with an overview of the emergence of cluster policy (Sect. 9.3) and with a summary of the cluster policy in Portugal (Sect. 9.4). In Sect. 9.5 we analyze the results of the survey launched to the clusters about open innovation activities. In Sect. 9.6 we present the main conclusions, including limitations of this research, implications for public policy and suggestions for further research.

9.2 Methodology

For the identification of open innovation activities in clusters we used the survey method, by building a structured questionnaire, appropriated for situations where the interviewer is not present or when is necessary to consider more precise questions (Hill and Hill 2000). Given that the questionnaire method should use, preferably, questions already tested (Almeida and Pinto 1995; Hill and Hill 2000), we looked at other questionnaires where open innovation was analyzed in the context of companies and/or clusters, namely Chesbrough and Brunswicker (2013), Cosh and Zhang (2011), Marques et al. (2010), Rahman and Ramos (2013) and Teixeira and Lopes (2012). In the case of international questionnaires, the questions were adapted to the Portuguese reality. The distribution and collection methods of these questionnaires were analyzed—the electronic mail (email) was the preferred communication channel used. Following this, we also used the email in the current research, given the low costs associated and given that all the members of the clusters have an email address.

The questionnaire included closed questions, mostly,[3] speeding up the response process and enabling better uniformity and simplification in the analysis of the responses (Almeida e Pinto 1995). The few open questions introduced in the questionnaire were designed to enable a more diverse gathering of information and identify other issues not covered by the closed questions. Before the questionnaire was released, we conducted a pre-test (Hill and Hill 2000), testing the type of questions, their relevance, explicitness, the order of the questions and the size of the questionnaire. This pre-test was conducted using similar entities that make part of the clusters analyzed (i.e. firm, R&D entity, technological intermediary, higher education entity and public institution). The suggestions have been analyzed and improvements introduced in the final version of the questionnaire.

The questionnaire had seven blocks of questions (Table 9.1): (1) characterization of the entity, (2) management of R&D and innovation activities, (3) participation in informal networks, (4) formal collaborations, (5) management of internal ideas, (6) management of intellectual property and (7) access to public funding. These seven areas intended to understand how entities organize open innovation activities, namely in the inbound and outbound process (see Jong et al. 2008, 2010). The seven areas of the questionnaire included 40 questions (Table 9.1).

We proceed to the construction of the questionnaire between February and March 2014, having been placed on the Internet in May 2014, using the Qualtrics online survey software platform. For the dissemination and distribution of the questionnaire, we contacted (by telephone and email) the management structures of each cluster, describing the nature of the questionnaire, requesting their cooperation to disseminate the questionnaire to all its members. The questionnaire was available to the members of the clusters through email, which included the characterization and objectives of the research as well as an electronic link that gave access to the questionnaire.

The questionnaire was launched to all the 837 unique members of the 15 clusters. We received 49 unique responses through the Qualtrics platform. This means that we had a 6 % rate of response, a similar rate of other online surveys that analyze open innovation activities in firms (e.g. Chesbrough and Brunswicker 2013; Cosh and Zhang 2011).

In this chapter we intend to develop a first exploratory analysis of the results. Thus, the objective was not to test hypotheses, but to respond to the

Table 9.1 Structure of the questionnaire

Area	*Main questions*
Characterization of the entity	1. Type of institution (enterprise, higher education, other entity) 2. Number of employees 3. Years of activity 4. Qualification of human resources 5. Expenditures on R&D 6. Exports as a percentage of total sales 7. Cluster where it belongs
Management of R&D and innovation activities	8. R&D management (organized by project; single department, outsourcing/process R&D projects, in part or in full) 9. Type of innovation developed (product, process, organizational, marketing) 10. Innovation process management (internal development/ with external partners)
Participation in informal networks	11. Participation in informal networks (user groups, participation in community/open source projects, research, collection or sharing of ideas and experiences via social networks, participation in networks of innovation and knowledge; sharing common workspaces with entrepreneurs, inventors, researchers, companies, R&D institutions, etc.) 12. Impact of the cluster in informal networks participation
Formal collaborations	13. Type of formal collaboration 14. Partners of formal collaborations 15. Reasons for collaboration with other entities 16. Impact of the cluster in formal networks participation 17. Absorption capacity—existing capacity in the institution to use the knowledge and technology generated externally 18. Barriers—factors hampering the use of knowledge and technology generated by external entities 19. Objectives of the transfer of knowledge and technology to other entities
Management of internal ideas (intrapreneurship)	20. Incentives to support employees to set up their own businesses (creation of spin-offs) 21. If there are no incentives, what are the main reasons? 22. If there are, what kind of support is provided? 23. Is there any support for the development of the ideas proposed by employees? 24. If there is no support, what are the main reasons? 25. If there are, what kind of support is given? 26. Impact of the cluster in the support to the development of ideas from the employees?

(*continued*)

Table 9.1 (continued)

Area	*Main questions*
Management of intellectual property	27. What is the IP protection strategy? 28. Is there external acquisition or IP licensing from other entities? 29. If there is not, why not? 30. If so, what kind of IP is acquired externally? 31. Is there IP sale or licensing to third parties? 32. If there is not, why not? 33. If so, what kind of IP is licensed to third parties/sold? 34. What are the main IP problems related to collaboration with other entities? 35. Impact of the cluster in the IP strategy?
Access to public funding	36. Was there use of public funding for the development of projects? 37. What kind of R&D/innovation projects was funded? 38. Main objectives related to the participation in funded projects 39. Main problems resulting from collaborations with external partners in funded projects 40. Main public funding programs used in the last five years

issues contained in Table 9.1, in order to better understand a reality not yet explored in Portugal (open innovation in clusters).[4] We also seek to ascertain the existing perception of the clusters members about the impact of their cluster in the adoption of open innovation practices.

9.3 The Emergence of the Cluster Policy

The importance of cluster analysis and its impact on the competitiveness of companies and nations is due to Michael Porter (1990, 1998) as well as the work of the geography of innovation and knowledge spillovers (Audretsch and Feldman 1996; Baptista 2000; Baptista and Swan 1998; Feldman 1999; Langlois and Robertson 1996), the agglomeration economy (Krugman 1991; Malmberg et al. 2000; Ottaviano and Thisse 2004), or the work of Marshall (1890) on the geographical proximity. The cluster definition of Porter (1990, 1998) is the most mentioned in academic literature, stressing the importance of geographical proximity of firms with other entities (suppliers, R&D and education entities, other firms, etc.), which compete and cooperate with each other in an interdependent relationship, with both formal and informal links (see European Commission 2008, for an analysis about the definitions of clusters).

The benefits of participation in a cluster have been linked to the positive externalities (Ketels and Memedovic 2008; Porter 1998), namely: access to specialized assets and resources—such as human resources—increasing productivity; learning economies, resulting from the interaction with customers and suppliers; reduction of transaction costs, given the proximity between the cluster's members; effects of diffusion of knowledge—spillovers—impacting the generation of ideas and creation of new businesses (Maercke 2013). The awareness of those benefits has led to the development of public policies (cluster policy) in order to maximize these benefits (European Commission, 2008; OECD 2007; Oxford Research 2008). Cluster policy can be defined as public policy directed to: (1) create, mobilize and strengthen a given cluster; (2) increase the impact of certain instruments (e.g. R&D incentives); (3) eliminate barriers and promote competition in order to facilitate the emergence of new clusters (Oxford Research 2008). Thus, cluster policies are essentially motivated by systemic failures and market failures (see Ketels 2013).

The growing attention that clusters have been on the part of policy makers in recent decades (Ketels and Memedovic 2008) is due not only to its impact on the innovation process, but also of its importance to the organization and implementation of public policies and investments aimed at economic growth (Christensen et al. 2012; Ketels et al. 2006). Therefore, clusters are an additional way to influence and achieve economic policy objectives by policy makers, stimulating innovation and growth through the development of policies directed at them. However, the degree of intervention and influence of public policies in the development of clusters is not consensual, being relevant to the context factors (including institutions) and the maturity of the clusters in the definition of public instruments and incentives (Vicente 2014).

The development of cluster initiatives has had more expression since the 1990s, and especially in the 2000s, particularly in Europe, USA, Australia and New Zealand, having been identified around 1400 cluster initiatives around the world in 2005 (Ketels et al. 2006). To this end, it has been important to the development of clusters policy, with greater emphasis in the 2000s, with public support being important in terms of financing instruments, but also at technical and organizational support (Sölvell et al. 2003). In the EU, cluster policy is recent (about 50 % of countries have started the support to clusters after 1999), with about 60 national cluster programs (with government support) under development in 26 countries, over the decade 2000 (Oxford Research 2008).

At the level of international institutions such as the Organisation for Economic Co-operation and Development (OECD) or the European Commission (EC), clusters are seen as a major instrument of the innovation policy. The OECD has given a significant importance to the cluster policy, with emphasis on the relationship established between clusters and the innovation process, but also for the role that public policies have on creating the framework conditions and active policies for the development/creating clusters (OECD 2007). Within the EC, the importance given to the cluster policy is reflected in various initiatives and communications within the Lisbon Strategy and the Europe 2020 Strategy. The importance of clusters at EU level has recently been strengthened by the European "Smart Specialization—RIS3" strategy, where the clusters are considered as important structures for the definition and implementation of the priorities of this strategy, given its role in promoting cross-collaborative networks and activities to the territorial/regional level (European Commission 2012, p.67).

This analysis of the emergence of clusters policy at the international level allows us to better understand the evolution of cluster policy in Portugal.

9.4 Cluster Policy Evolution in Portugal

The first approach to cluster policy in terms of political discourse in Portugal, has origins in the study ordered by the Portuguese Government to Michael Porter's Monitor Company, in 1992. This study put forward a set of recommendations on clusters that Portugal should develop in order to make its economy more competitive. The "Porter Report" was presented in 1994,[5] suggesting that the Portuguese economy should specialize in areas where it already had comparative advantages, giving as an example the textile, wine, cork, footwear, forest products or molds (Monitor Company 1994). It was a sectorial and static view, since the study presented made no reference to the evolution of these areas over time, nor had considered other emerging areas where Portugal could in the future be competitive (e.g. renewable energy or in information and communication technologies). To Michael Porter, Portugal should bet only on so-called traditional sectors, ignoring the possibility that Portugal would be able to develop skills in higher value-added areas or technological intensity sectors.[6]

After the Porter Report, in the period 1995–2001 there were no references to the cluster policy at political discourse level. Only in 2001, the cluster approach was included again in Governmental policy documents, based in a study elaborated by the Portuguese Government, with the mapping of existing and emerging clusters in Portugal, but in a final demand perspective and not on a sectorial/industrial perspective (Cardim and Santos 2003). This study identified cross-competitive factors for the development of the cluster policy, and put forward a proposal to develop "mega-clusters" in Portugal (aggregators of multiple clusters), namely in the fashion area, agro-food, habitat, leisure, mobility, health/personal services and entertainment (Gabinete do Proinov 2002). In other words, the proposed clusters were based on the articulation and cooperation between related and complementary areas, oriented according to global markets' final demand and needs. In the period 2003–2005 this approach was abandoned, although there were some Government initiatives to support the creation of business cooperation networks and link between business and science and technology institutions.

In 2005, cluster policy was taken up by the Governmental Technological Plan, where was proposed the creation of "Poles of Competitiveness and Clusters". This new orientation had correspondence in the orientation of funding instruments for this purpose, particularly in terms of EU funds managed by the Portuguese authorities (CSF/NSRF).[7] In this sequence, the public support to clusters was formalized in 2009, with the recognition by the Portuguese Government of 11 poles of competitiveness and 8 clusters,[8] as well as the respective management structures.[9] This recognition had the expected duration of three years (2009–2012).

In 2012 was started the evaluation process of the cluster policy (the clusters recognized in 2009), through an international tender, a process followed by a steering group, composed of national and international experts (advisory Committee).[10] The result of that evaluation was presented in April 2013,[11] with the study's findings to mention that "are recognized as positive the efforts made and called for the continuity of the cluster approach" (SPI and innoTSD 2013, pp. Xi), pointing as aspects to improve in the cluster Policy a greater robustness in the (i) coordination and management model (governance), (ii) financing and sustainability, (iii) professionalism in the management of clusters, (iv) setting ambitious and targeted strategies for internationalization and (v) a better integration with entities public (SPI and innoTSD 2013).

In brief, the cluster evaluation process points to weaknesses in cooperation between the entities belonging to clusters, with the existence of few collaborative projects between companies (both within and between different clusters), the lack of partnerships or projects with international organizations, the tiny participation in technology platforms or in international R&D projects, as well as the small number of formal collaborations between entities belonging to the cluster or between clusters themselves (SPI and innoTSD 2013, pp. 55–59). Being the collaborative processes essential for the development of open innovation activities, these facts can mean the existence of less favorable conditions for open innovation development. Thus, in Sect. 9.5 we analyze how open innovation practices are developed in the Portuguese clusters, exploring the results of a questionnaire built and launched for this purpose.

9.5 Open Innovation in Clusters in Portugal (Main Results of the Survey)

The responses to the survey allow the identification of the more developed open innovation areas (and their activities), the main constraints and the impact of the cluster in the adoption of open innovation by its members. In order to have a better perception of the adoption of open innovation, we proceeded to the classification of the responses regarding open innovation areas as well as the impact of the cluster in open innovation adoption, proposing the following typology of classification (Table 9.2).

Based on this classification, and combining these two dimensions, one can view (i) how open innovation is being developed in the clusters in Portugal (5.1) (ii) if being part of a cluster is favorable or not for the development of open innovation practices (5.2) and (iii) the main barriers for open innovation adoption (5.3).

9.5.1 How Open Innovation Is Being Developed in the Clusters

Through the survey responses one can say that there is a group of activities where open innovation approach is already a reality in the clusters's members (namely in informal and in formal collaborations and in ideas development), another group of activities dominated by closed innovation (IP management, innovation management and in the support to the creation of start-ups/spin-offs) and activities that appear to be in transition from the closed to the open innovation model—R&D management and use of public funding (Fig. 9.1).

Table 9.2 Typology of classification of open innovation areas developed by the clusters members

Open innovation areas	*Impact of the cluster in open innovation adoption*
>60 % positive responses: open innovation model is dominant	>60 % positive responses: a high impact
<40 % positive responses: closed innovation model is dominant	<40 % positive responses: a low impact
Between 40 and 60 %: in transition from the closed to the open innovation model	Between 40 and 60 %: a moderate impact

Source: Own elaboration

It is in the formal and informal collaborations with external parties (whether in inbound or outbound process) that open innovation is felt most, as these are common and are developed by more than 80 % of the members of the clusters that responded to the survey (upper quadrant right, Fig. 9.1). Internet usage is the main mean for the development of informal relationships, while collaborative R&D projects (with businesses and national R&D entities, but also international) are the most frequent form of formal relations. The entities that belong to clusters also adopt open innovation in the identification, selection analysis of the technology and knowledge generated externally, and in their integration in the production process (absorption of knowledge/inbound). Regarding the transfer of knowledge and technology activities (internally developed) to other entities (outbound), although less frequent than absorbing activities, are mentioned by most part of the respondents, namely through licensing agreements and the creation of joint ventures.

When we look to the intrapreneurship development, the respondents follow the open innovation approach in relation to supporting the development of ideas, but have an opposite attitude in supporting the creation of new businesses by their workers, that is, the closed innovation model is dominant here (lower left quadrant, Fig. 9.1). Open innovation is still not a reality for most of the responding entities at the level of IP management (acquisition, sale and licensing), R&D and innovation management, where prevail closed innovation practices. The acquisition and/or licensing of IP developed externally is a reality for few entities (14 %), while the sale/IP licensing to other entities occurs in a higher percentage of entities, although it does not happen in the majority of the entities (66 %). In innovation

Fig. 9.1 Open innovation in clusters

management, the percentage of entities that operate in the closed innovation model is still high—65 % of organizations that do not develop innovation of the development is made only indoors (product/process/marketing/organizational). Both in R&D management and in financing instruments there is a higher balance between the percentage of entities operating in the closed innovation and in the open innovation model, that is, these two areas are in transition to a more open innovation approach.

9.5.2 Belonging to a Cluster Supports the Development of Open Innovation Practices

The data collected through the survey allows to verify the impact of the cluster in the adoption of open innovation in each of the areas analyzed, based on the perception of its members. The areas where the cluster has contributed more to the adoption of open innovation was at the level of informal networks and formal collaborations, including absorption and external transfer of technology and knowledge, these also being the most used areas by the respondents, that is, where open innovation predominates (upper right quadrant, Fig. 9.1). On the contrary, the areas where most part of the responding entities considered to have been a minor impact of the cluster in open innovation adoption are also those where open innovation is felt less, that is, where the closed innovation mode is dominant (lower left quadrant, Fig. 9.1). The only exception lies in supporting the development of ideas, where most of the respondents said that the cluster had little influence on the development of initiatives in this direction, although it is an activity present in 78 % of entities (lower right quadrant, Fig. 9.1). In terms of financing instruments, belonging to a cluster has advantages in terms of positive discrimination in the project analysis (under the COMPETE/QREN program), and a financial support to promotion and networking activities inherent to the management of each cluster. However, we found that there are a high percentage of entities that do not use public funding (29 %), while those who use mention that about 80 % of the funding was intended to support collaborative projects.

9.5.3 Barriers to Open Innovation Adoption

Through the analysis of the survey it is possible to identify six major barriers (Table 9.3): (1) the lack of financial resources and/or budget constraints (to seek and incorporate ideas and external knowledge, support the development of ideas and the creation of spin-offs); (2) the lack of information (on how to develop new ideas); (3) the deficit of internal skills (to absorb external knowledge, take advantage of the internal ideas, to manage the IP or in the relationships with external partners); (4) time management problems, which hinders the activities related to the absorption of knowledge, the development of ideas or the management of collaborative projects; (5) the competitive threat of fear at the level of IP protection (copy fear) or in the support of workers to set up their businesses (potential competitors); (6) the implementation or the advantages associated with certain activities (particularly in the protection, acquisition and licensing of IP or in the support issues related to the management and coordination in general), the level of IP management of external networks and involvement in collaborative projects. There were also mentioned other constraints, such as the costs associated with registration, maintenance, acquisition/licensing of IP, the differences in organizational culture with external entities or the trust deficit with external partners.

If the constraints refer mostly to existing deficits at the level of entities (internal skills, time management, network management, budgetary constraints), others may be associated with contextual factors—external entities—such as those related with IP costs—while others may derive from an incorrect functioning of the market (lack of information about the advantages and the ways of open innovation implementation). These deficits

Table 9.3 Main factors that constrains the adoption of open innovation in clusters

Areas	*Identified constraints (in order of importance)*
Barriers to absorption of knowledge (*inbound*)	Lack of financial resources Time constraints Lack of internal skills Differences in organizational culture with external partners IP management problems Distant location of external partners Lack of trust in external partners
No support for spin-offs development (*outbound*)	Lack of financial resources or logistical conditions High degree of specialization/lack initiative of workers Unawareness of the advantages associated with the creation of spin-offs Lack of information about the kind of support that can be given Fear of competitive threat
No support for ideas development *(outbound)*	Lack of financial and/or logistical resources to support ideas Limitation of working hours Preference for collaboration with external entities to capture new ideas/suggestions for improvement Lack of internal skills to take advantage of the ideas proposed
Lack of IP strategy *(inbound/outbound)*	Unawareness of the advantages and/or forms of protection Difficulty in demonstrating the novelty of the invention Costs associated with the registration/application for IP protection Costs associated with maintenance of IP rights Copy fear (by competitors) Costs associated with IP litigation
No acquisition/IP licensing from others *(inbound)*	There is no necessity High cost of acquisition of external IP Lack information about the mechanisms for the acquisition of external IP
No selling/IP licensing to others *(outbound)*	Lack of information on the forms of IP sale to other entities and licensing advantages Fear of competitive threat

(*continued*)

Table 9.3 (continued)

Areas	*Identified constraints (in order of importance)*
IP management through organizational boundaries *(inbound/outbound)*	Problems with the ownership of IP rights Underestimation (by external partners) of the value of the IP IP acquisition costs Internal difficulties in the integration and management of the IP acquired externally Disagreement with external partners in the form of use of IP
Funded projects developed with external entities *(inbound/outbound)*	Coordination problems (many partners involved) Time management problems Difficulty in project management and sharing results with partners IP protection conflicts Skills gap between the partners involved

anticipate the need for developed mechanisms to encourage the adoption of open innovation, either through the entities that belong to the clusters (via greater awareness about the importance of open innovation or the acquisition of new skills) or through external entities, such as the public entities acting on market failures (e.g., via dissemination of information, a more friendly intellectual property framework of financing instruments).

9.6 Conclusions, Policy Implications and Further Research

The n-Helix literature provides a basis for considering intermediate structures where innovation happens. Clusters is such an instance where multi-actor innovation processes take place. The results of the research show that open innovation activities are already a reality in the entities that belong to the Portuguese clusters. Still, they are not adopted in the same way; there are some open innovation activities more used than others. Despite the constraints identified, the analysis seems to suggest that being in a cluster favors the adoption of a more open approach to innovation—with greater intensity in the formal and informal networks, to a lesser intensity in the IP management and with moderate intensity in the intrapreneurship activities and in the transfer of technology and knowledge to external entities.

Concerning policy implications, the results of this analysis suggest the need for additional mechanisms to encourage the adoption of open innovation, either through the entities that belong to the clusters (e.g. via greater awareness about the importance of open innovation) or through external entities such as the public entities acting on market failures (e.g. dissemination of technical information, a smarter intellectual property framework). Public policy can have a major role in enhancing the development of open innovation activities in clusters, through the correction of some market and systemic failures. In this sense, cluster policy should be supported in order to enhance open innovation.

In the future it would be interesting to have a comparative study involving clusters from other countries (at or below the technological frontier). Also comparing open innovation determinants of clusters with entities that do not belong to clusters would create a deeper comprehension of the theme.

Notes

1. In 2009, the Portuguese Government officially recognized 19 clusters.
2. Survey launched to the members of the 16 clusters of the “Portugal Clusters” association (3 of the 19 recognized clusters did not integrate this association). One of the 16 clusters did not respond to the survey.
3. The respondents selected the questions among those who were presented.
4. If there is a participation of most respondents in the seven areas of Table 1.1, we can say that in such cases, the approach of open innovation is predominant (otherwise, closed innovation will be the dominant approach).
5. The report was entitled “Porter Report: Building Competitive Advantage in Portugal”.
6. The “Porter Report” indicated eight recommendations to improve the competitiveness of Portuguese companies: “Concentration on sophisticated customers”, “Formulate competitive strategies”, “Increase productivity”, “Cooperate with customers and suppliers”, “Creating networks”, “Building a home base of competitiveness”, “Developing civil society”, “Investing in human capital”.

7. Community Support Program (QCA III) and National Strategic Reference Program (QREN 2007–2013).
8. The poles of competitiveness were more orientated to global markets, while clusters had the national market as their "natural market". List of clusters available at http://www.pofc.qren.pt/areas-do-compete/polos-e-clusters
9. The members of the managing structures consisted of five members, elected by the members of each cluster.
10. The advisory committee included a set of recognized experts at national and international level in the area of clusters. See composition in SPI and innoTSD (2013, pp. Xiii and ix).
11. Report available at http://tinyurl.com/bo2bzfu

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CHAPTER 10

Conclusion

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This book aims at defining the impact of public policies on innovation activity and economic growth in the Organization for Economic Cooperation and Development (OECD) countries. We take inspiration from the Quadruple Helix (QH) Innovation Systems Conceptual Framework. We start by describing a theoretical economic growth model built in order to frame analytically an innovation economy, and we then assess the role

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played by governments and by productive public expenditures in a growing innovation economy.

The two chapters (Chaps. 2 and 3) of the book lead us to the following conclusions:

Our theoretical model presented in Chap. 1 can lead to two predictions: (i) an increase in the complementarities among the different production units and (ii) an increase in productive government spending, leading to a higher and sustainable economic growth. We also analyzed theoretically, in detail, issues related to productive public spending and the importance of complementarities between the different production units in the innovation economies and in economic growth. In addition, we examined the relevance of considering the nature and cost of productive investment and the importance of public policies to achieve higher economic growth. In the innovation model proposed by QH, the government provides a pure public good in the form of productive spending in education, health, technology infrastructure, technology services, innovation services, and regulation, in order to increase the productivity across all inputs. The model shows analytically that the increase of productive public spending leads to higher economic growth in QH economies. To study how the economy converges to equilibrium or to a steady state, we performed an analysis of "dynamic transition" using numerical integration. The main conclusion of this study is that an increase in the proportion of output

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spent under the public spending has a positive effect on economic growth in the short term (first-level effect), medium term (dynamic transition), and long term (steady state).

Two main conclusions can be drawn from the results of the empirical model obtained in Chap. 3:

(i) The four pillars or helix strands—companies and industry, academia and technological infrastructure, government, and consumers—support the economy. We have shown an equivalent, complementary, and equally important role of each of the four strands of the helix, where innovation is the engine of growth and is performed by society in a structure of a single productive sector.
(ii) We also highlighted the fact that public spending has an important economic role, as an increase in government spending leads to economic growth.

Chapter 4 characterizes innovation policy in three different dimensions: multi-rationales, multi-actors, and multi-level governance. Policy rationales play an important role because policy-makers may use them as ex-post justifications to legitimize policy decisions already taken. In the domain of innovation where business firms play a major role, the author proposes that innovation policy-mixes should consider to segment firms by innovation capabilities, and to complement the multi-actor innovation policy-mix the innovation system as a whole could also be considered as a target. Finally different types of innovation policies are more efficiently delivered at different governance levels.

Chapter 5 seems clear that the qualities of collaborative leadership and the success of any smart specialization strategy are highly dependent on the robustness of institutional and governance structures and the geographies of context and cannot play second fiddle to organize and consolidate QH dynamics feeding the design of smart specialization strategies.

Chapter 6 concludes that the design of a road map of innovation based on the TFP and EU Innovation Scoreboard indicators provide a rigors framework for regional stakeholders to address policy design and practice implementation.

Chapter 7 confirms that there is a need to further develop research exploring connections between innovation determinants, innovation life-cycle dynamics, and innovation performance measurement. Further research should be dedicated to develop a digital tool facilitating integration of the innovation measurement framework in business management processes and systems, improving evidence-based decisions.

In Chap. 8 Quadruple Helix Innovation Systems Conceptual Framework is considered an urban innovation environment oriented to the co-creation of creative solutions to solve urban problems and to answer to the city's future challenges. Future research at this level will be dedicated to quantitative analysis of the smart city actor's collaboration.

In chapter 9, the results of this analysis allows the understanding of the importance of belonging to a cluster for the pursuit of open innovation activities and contributes to a debate on the need to develop more "pro-openness" innovation policies under QHT and NSI approaches.

According to Berthomieu et al. (2009), since its origins, the purpose of the macroeconomic theory is to design policy interventions for the government to control inflation and unemployment, and to promote economic growth. The aim of the macroeconomic theory is to study the nature and causes of the wealth and prosperity of nations, and to propose economic policy measures to improve the life of civil society. The authors analyze in this chapter the arguments of two "Nobel Prize" winners on the state of the macroeconomic theory. Phelps (2007) argues that the models should take note of the aspects of modernity brought by innovation, and insists, in particular, on the importance of the dynamics of individual entrepreneurs, and of education, and comments on an innovative and inclusive economy, "the Good Economy". According to Akerlof (2006), rules must be put in place, which he calls "forgotten motivations", for the neo-classical economists, on the behavior of agents, other than those that maximize their satisfaction or profit, namely manifestations of formal and informal institutions. These are the two aspects that we sought to articulate in our book.

In this book we wanted to present, in a single debate, different visions resulting from the co-existence of diversity and at the same time complementary and equilibrium (or no equilibrium sometimes) between different sciences, in order to successfully reveal the complexity of economics, considering the different levels of economic analysis, namely meso, micro, and macroeconomics.[1] Also, it seems crucial to consider the theoretical foundations of the economy as a complex system.

This book wants to be "a small contribution" for an essential debate which is presently ongoing!

10.1 Agenda to a Future Research

The agenda for research in the future therefore includes: developing new and more complex models and new econometric analysis and a possible way to do this is build new models based on *Firm Centred LL Models, Public Centred LL Models et Citizen Centred LL Models and use ECM analysis.*

The *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework* was developed and designed almost 10 years ago (Carayannis and Campbell 2009, 2010, 2012, 2014; Carayannis et al. 2012; Campbell and Carayannis 2013a, b, 2016). In fact, in the article published in *International Journal of Technology Management* (IJTM), back in 2009 (Carayannis and Campbell 2009), it was the first time that the concept of the "Quadruple Helix", in reference to knowledge production (research) and knowledge application (innovation), was released in context of a peer-reviewed journal. *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework* is being motivated, carried, and driven by the understanding and the need to expand the earlier concepts of "Triple Helix" (Etzkowitz and Leydesdorff 2000; Leydesdorff 2012). The *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework* brought into perspective the knowledge society, knowledge democracy, social ecology (environment), and sustainable development for the purpose of advancing knowledge production and innovation activities in the knowledge economy. More specifically, the *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework* factored in civil society, media-based and culture-based public, quality of democracy, arts (and artistic research and arts-based innovation), and the environment. The project of ARIS (Arts, Research, Innovation and Society) contributes to these efforts (Bast et al. 2015).[2]

The Quadruple Innovation Helix concept (Carayannis and Campbell 2009) *is the synthesis of top-down policies and practices from Government, University and Industry, balanced and shaped by bottom-up initiatives and actions by Civil Society.* In addition, of currency and significance is the complementary expansion and completion of the Quadruple Innovation Helix by the concept of the Quintuple Innovation Helix (Carayannis and Campbell 2010), where an all-encompassing and moderating factor and pillar was added, *namely, the fifth dimension, namely the Environment.*

The book presented here and analysis represent a next step in the evolution of *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework*, where (1) the Quadruple Helix Innovation Systems Conceptual Framework has been brought closer to an empirical validation and testing, and where (2) Quadruple Helix Innovation Systems Conceptual Framework was utilized for key reference points for a model-building that focuses on analyzing possible links between innovation and economic growth.

Early empirical results and early empirical findings (see the sections in this book and to this book) allow the formulation of the following propositions that can serve as hypothesis for further research: (1) co-operation, collaboration, and information-sharing of firms is importan; (2) government and government policies play a key role in and for innovation economy; and (3) Quadruple Helix Innovation Systems Conceptual Framework based growth theories provide predictors for economic growth, because a diversity of systems and sectors, as are being described and looked at by *Quadruple and Quintuple Helix Innovation Systems Conceptual Framework*, are important for explaining and promoting innovation.

In what follows we present some insights about the econometric methodology used and about other methodologies that in our opinion might contribute to broaden our knowledge about the empirical relationships we are testing for. Notwithstanding, it should be mentioned that our brief reflection only deals with econometric methodologies that might be suited to estimate endogenous growth models for the Quadruple Helix Innovation Systems Conceptual Framework.

The use of cointegration panel techniques allowed us to test for long-run equilibrium relationships between our variables of interest, to characterize transitional dynamics by estimating ECMs equations, to identify the role played by our variables in the adjustment process to long-run equilibrium and the causality between them in the short run. Furthermore, by identifying the variables that pertain to the cointegration space from those that do not belong we were able to further differentiate our variables with relevant consequences for economic policy. Heterogeneity between countries was addressed in our empirical analysis with the help of the estimator panel DOLS for heterogeneous coefficients that was used to test for long-run equilibrium. The robustness founded for these empirical models lead to far more reaching consequences than to be able to confirm or infirm theoretical predictions of the Quadruple Helix Innovation Systems Conceptual Framework. In fact, it allowed to test for policy QH hypotheses, namely the country (regional) specific nature of innovation policies under the Quadruple Helix Innovation Systems Conceptual Framework was confirmed.

We consider that our econometric strategy should be complemented in the near future with

(a) the inclusion of econometric techniques, such as quantile regressions that address the possibility of a different behavior of the covariates along the distribution of the dependent variable; and (b) the inclusion of econometric techniques such as threshold models that allow to test for nonlinearities and to identify different economic models in the presence of thresholds.

Future research could involve the introduction of social capital (trust) between firms, and its impact on innovation activities and economic growth**.**

A quantitative empirical validation and operationalization for OECD countries with insights for theory, policy, and practice was the underlying desire of the analysis here. *This can be regarded as a next step toward development and design in the building of metrics for Quadruple and Quintuple Helix Innovation Systems Conceptual Framework.*

Notes

1. This is an Economic problem. This discussion is not peaceful in our times. In general the heterodoxies currents find in interdisciplinarity a point of reference and an indispensable condition to take account the complexity. On the other hand, some orthodoxy like the liberal doctrines and the ultra-liberal ones, with the scientificity dream about the natural science and Economy as science exact, which has been defended by W. Stanley Jevons in 1871, refuse this vision. Nevertheless, we know that many economic theories only survive, even if reality "counterfeits them", with recurs to "imunisators stratagems", with inductions or assumptions. Although and if we cannot neglect the neo-classic values contributions in the economic theory, however it is necessary to note that many scientists are unable to include/understand how much a "plurality of conjectures in competition is essential" (Popper). The scientific practice in economy is not only a question of "enigmas" resolution (Kuhn) or building some models lógique-abstracts. The discipline characteristics (as social science), imply that we can never forget the ground where it plunges their roots. Arthur B., Lane D., and Durlauf S. (1997), The Economy Year Evolving complex system II, Santa Fe Institute Studies in the Science off Complexity.
2. See also the website to the ARIS project: http://www.dieangewandte.at/aris (and more specifically: http://www.dieangewandte.at/jart/prj3/angewandte_aris/main.jart?j-j-url=/quadruple_helix).

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