FACULTY OF ECONOMICS AND MANAGEMENT

«MASTER IN BUSINESS ADMINISTRATION »

MASTER THESIS

THE ROLE OF INNOVATION AND R&D ON AN ORGANISATION'S ECONOMIC PROFILE – A COMPARATIVE ANALYSIS

ATHANASIOS ARETOS

SUPERVISOR NAME

SOTIRIS KARKALAKOS

MAY, 2017

Ανοικτό Πανεπιστήμιο Κύπρου

Faculty of Economics and Management

Μεταπτυχιακό Πρόγραμμα Σπουδών

MASTER IN BUSINESS ADMINISTRATION

Μεταπτυχιακή Διατριβή

The Role of Innovation and R&D on an Organisation's Economic Profile – a Comparative Analysis

Αθανάσιος Αρέτος

Επιβλέπων Καθηγητής
Σωτήριος Καρκαλάκος

Η παρούσα μεταπτυχιακή διατριβή υποβλήθηκε προς μερική εκπλήρωση των απαιτήσεων για απόκτηση μεταπτυχιακού τίτλου σπουδών στο MASTER IN BUSINESS ADMINISTRATION από τη Σχολή ECONOMICS AND MANAGEMENT του Ανοικτού Πανεπιστημίου Κύπρου.

Μάϊος 2017

BLANK PAGE

Abstract

In the modern business environment, the access to information and the use of knowledge are important factors for the corporate success of a firm and for achieving a competitive advantage. To foster innovation, many firms tend to strategically anticipate the challenges arising from the complexity of their industries by linking their innovative activities to the business models. Open businesses are more likely to engage in R&D and achieve their long-term goals through cross-industry or cross-border innovation.

The study performs a comparative analysis between Germany, Greece, United Kingdom and the United States to identify where Greece stands compared to the other countries in terms of innovation and R&D. Although Greece lags behind in R&D compared to the European peers and the United States, it seems that in the Greek business practice, there are examples of successful absorption, adaptation and diffusion of technology and innovation. Greek managers have proven to be open to the integration, adaption, and generation of innovative processes, products and business models. Conclusively, the study demonstrates that firms which effectively utilise the innovation mechanisms to attain new knowledge are more likely to successfully engage in R&D and benefit from innovation.

Keywords: patent, innovation, R&D, competitiveness, licensing, intellectual property rights

Acknowledgements

I would like to express my sincere gratitude to my supervisor, Prof Sotiris Karkalakos, for his guidance, valuable monitoring and patience. His expertise and intellectual support made it possible for me to work on a scientific area that was of great interest for me.

I also take this opportunity to thank my colleagues in Glasgow and Preston for creating such a supportive and encouraging working environment. Finally I would like to thank Maria Pitsillou for her understanding and for accommodating a smooth presentation process.

Contents

List of tables

List of Figures

Chapter 1
Introduction

Economists have argued that when there is a single and isolated innovation in prospect, patents are efficient tools to promote innovative activity. However, innovation does not necessarily occur in isolated settings as previous innovations often stimulate subsequent improvements. Furthermore, the production of many new high-technology products often requires numerous complementary innovative components, each of which may be protected by one or more patents. These facts give rise to a proliferation and fragmentation of intellectual property (IP) rights.

This complexity of modern technology has forced firms to interact over patent portfolios that have allegedly resulted in various inefficiencies. For instance, some commentators believe that patent portfolio races are mainly derived from strategic purposes, such as to negatively affect competition and to increase the transaction costs for firms operating in the same or similar technological areas. Evidence on the value of patents and R&D in European firms between 1991 and 2004 suggests a positive and significant correlation between R&D, patent stocks and "quality"-weighted patents and argues that the aim of the patents is to build portfolios rather than protecting the inventions per se (Hall et al., 2007). The fact that these portfolio races are taking place in industries that did not traditionally rely on patent protection has raised the question as to whether the current IP system is adequately functioning or additional policy actions are necessary to lessen the effect of certain externalities that have emerged. Among these proposals are measures to prevent large volumes of patent applications, limit the scope of patent protection or to apply stricter regulation of licensing practices via competition rules. Also, although the licensing activity accounts for a significant share of economic activity, it is not evenly distributed between the sectors of the economy, thereby leading to inefficiencies (Regibeau and Rockett, 2011).

The above context might raise the question of whether optimisation can be reached by changing the innovation policy. However, before any policy change is made, one should be fully aware of the functioning of institutions and their interaction with firm behaviour. In spite of numerous contributions by many prominent scholars, there is no generally accepted theoretical framework for conceptualising the dynamics between R&D and patent portfolios.

Informal analysis of cumulative and complementary innovations abounds in the literature; however, there is a need for a more precise and analytically articulated analysis of firms' preferences on accumulating patents. This thesis aims at filling this gap by providing analytical and quantitative models of the consequences of patent proliferation. The cost structure of firms holding multiple patents for a certain product is particular; therefore, it needs a particular analysis.

This thesis is composed of three key topics that explore different facets of firm performance, namely innovation, research and development (R&D), and cross-border economic activity. These topics document a systematic shift in the nature of innovation and R&D towards firms' performance. Using empirical evidence, the study will demonstrate that changes in the nature of innovation had differential effects on the performance of the industries in selected countries. It will also provide evidence suggesting that human resource constraints have played a key role in preventing firms from adapting to the documented shift in IT innovation.

1.1 Research aims and objectives

The study seeks to measure innovation externalities and patent output at the firm and aggregate level. To that end, the research aims and objectives are summarised as follows:

1. To investigate whether firm structure plays a role in innovation and R&D
2. To determine the relationship of innovation and R&D with economic activity.
3. To assess the role of licensing in the rate of technological innovation.
4. To investigate the impact of cross-industry differences in innovation output and growth.
5. To determine whether the protection of intellectual property rights inhibit innovation.

1.2 Research Questions

Based on the study's aims and objectives and the literature review that follows in Chapter 2, the research questions aim to identify a cause and effect relationship between innovation and R&D with economic activity. The research questions are the following:

1. RQ1: Does firm structure play a role in innovation and R&D?
2. RQ2: Is there a cause and effect relationship between innovation and R&D and economic activity?
3. RQ3: Is licensing positively correlated to the technological innovation?
4. RQ4: Do cross-industry differences have an impact on innovation output and growth?
5. RQ5: Does the protection of intellectual property rights inhibit innovation?

1.3 Contribution and importance of the study

Given the complexity of the topic at hand, there are many aspects that one could investigate innovation and its impact on economic growth. The study takes into consideration the fact that industries which did not traditionally rely on patent protection, nowadays desire to protect their intellectual property rights. Therefore, given that technological innovation is considered as a key force in economic growth, the study seeks to fill the gap in the existing literature by approaching the topic at hand from the policy perspective and the need to lessen the effect of certain externalities that have emerged. Furthermore, it contributes to the existing literature with suggestions and policy recommendation for further research.

1.4 Methodology

The study implements empirical evidence research method with empirical observation and collection of primary data from a sample of firms that engage in innovation and R&D. By investigating the causality between innovation and R&D with economic activity, the study encompasses the role of intellectual property rights and government prizes. Moreover, qualitative research is deemed as necessary in order to present the theoretical framework of the study. Using qualitative research, the study presents empirical evidence from secondary literature sources, i.e. published books, articles in

academic journals and international publications, to define the framework of research and identify the causal relationship between innovation and R&D to firm growth.

1.5 Structure of the research study

After the introductory chapter, the study is structured as follows:

Chapter 2 presents the literature review on innovation, R&D and patents and provides the theoretical framework for the topic at hand.

Chapter 3 presents the theoretical background on innovation and R&D, providing a range of definitions and aiming to explain how these attributes can contribute to firm performance.

Chapter 4 performs a comparative analysis of R&D spending in selected countries, i.e. Germany, Greece, the United Kingdom and the United States as well as on patent activity in the OECD countries, including those mentioned above.

Chapter 5 illustrates and analyses the cross-border ownership of inventions, the grants by private agencies and NGOs, the GDP growth and the employment rate in the selected countries. It also performs a comparative analysis to identify where Greece stands compared to the other countries in terms of innovation and R&D.

Chapter 6 presents the conclusions that can be derived from the analysis, as well as limitations of the study and directions for future research.

Chapter 2
Literature Review

Innovation is crucial for sustaining growth and economic development in the present volatile macroeconomic environment. Firms seek innovative solutions and invest in R&D as a means to regulate their development activities and achieve economic growth. In this context, intellectual property rights (IPRs) represent one of the key innovation-led strategies in modern economies, especially in those that have the incentive to focus on R&D and generate enhanced knowledge for the public good.

The concept of innovation has been studied by many researchers and entrepreneurs. Its contribution to the growth and prosperity of a business is well established. Innovation is more than a system of new processes, products or services. It is the pursuit and acquisition of a competitive advantage on the part of an enterprise based on: a) basic research, which takes place in academic institutions or specialised laboratories for the purpose of invention; b) applied research, which requires the transfer of invention to a new product or a new production process directly connected to the market; and c) the diffusion of innovation to other firms through the exchange of knowledge.

The relationship between innovation, R&D and economic activity is sustained by several studies. Evidence of entrepreneurial activity in 13 developed economies between 2002 and 2007 has highlighted a positive correlation between innovation and entrepreneurship, monetary policy and social climate. In the setting of economic activity, entrepreneurship is positively related to GDP and promotes innovation (Galindo and Méndez, 2014). A study on 90,000 firms in West and East European countries has established a link between innovation and entrepreneurial growth, arguing that innovation activities can significantly influence firm performance (Hashi and Stojcic, 2010). Also, a study on Austrian firms that employed R&D between 1995 and 2006 concludes that R&D intensity is directly and strongly correlated to

employment and sales growth for these firms (Falk, 2012). However, there is a different impact of innovation on firm growth. For instance, in large US pharmaceutical companies employing R&D during the period 1950 and 2008, R&D has not contributed to the firm's growth, whereas in smaller firms R&D was reported to positively contribute to firm growth. These results suggest that the impact of R&D on firm growth is highly conditional upon firm-specific features such as firm size and patenting efforts (Demirel and Mazzucato, 2012). Evidence on 2,777 R&D firms in the period between 1921 and 1938 supports that 59% of all firms and 88% of publicly-traded firms engage in patents. Surprisingly, these percentages are significantly higher than those identified in contemporary R&D firms, suggesting that industry and firm size may play a role in a firm's decision to engage in innovation (Nicholas, 2011).

The relationship between the patent strength and economic development has also been explored. Patent strength is inversely correlated to domestic patent filings and positively correlated to foreign patent filings in the developing economies. In contrast, in the developed economies, patent strength is positively correlated to domestic patent filings and inversely correlated to foreign patenting. Hence, stronger patent rights have varied effects on innovative activity, depending on the level of economic development of the country as well as nature of patent reform (Allred and Park, 2007). Although innovation is positively related to per capita outputs both in the developing and developed economies, the stronger economies are more likely to increase their innovation output by investing in R&D. In fact, a 1% percent increase in innovation can raise per capita income 0.05% both in OECD and non-OECD countries, while a 1% rise in R&D activities can enhance innovation by 0.2% only in large 'Organisation for Economic Co-operation and Development' (OECD) economies (Ulku, 2004). Analysis of a sample of 244 Chinese high-tech firms has proven that firms in emerging markets can demonstrate better innovation output based on their R&D structure and institutional development, which both can positively contribute to innovation performance (Ying et.al. 2016). Also, the number of patents granted, the degree of patent competition, and the suitability of a patent are positively correlated to financial performance (Maresch, et.al. 2016). On the other hand, there is an increasing debate whether patents contribute positively to firm-level performance. Boldrin and Levine (2013) argue that, in essence, there is no empirical evidence that patents contribute to innovation and firm-level productivity,

unless one measures productivity with respect to the number of patents awarded. Although patents may partially contribute to the increase of incentive to invent, they are not strongly related to innovation per se. Thus, patents should be unrelated to lobby effects and government legislation to be able to foster innovation (Boldrin and Levine, 2013). The growth of R&D spending is not strongly related to the profit growth of a firm, but it follows the growth in sales and employment. Furthermore, the impact of R&D growth is different on growing or shrinking firms, indicating that firms which are less R&D-oriented experience a negative growth shock as compared to the more R&D-dependent ones which follow a positive shock (Coad and Rao, 2007).

In terms of financial shock, various studies have investigated the relationship between economic crisis and innovation. The impact of the global financial crisis has decimated the economic resources of many countries around the world; however, innovation has the potential of pulling the economies out of the recessionary phase (Hausman, and Johnston, 2014). In fact, many economies implemented supportive policies to innovation, focusing on infrastructure investments and the provision of innovative financial solutions to facilitate the provision of funds to businesses. Others, including the Greek economy, have cut back on innovation expenditure to protect their scarce financial resources (OECD, 2012). This strategy relates to the closed model of an economy, which lacks extroversion and is highly unlikely to overcome the financial constraints. Businesses that increased their innovation budget during the crisis capitalised on fast-growing segments and pursued new product development strategies (Archibugi, et.al, 2013). Moser and Nicholas (2013) have identified a 40% surge in the U.S patent since 1851, suggesting that the selection of prize-winning technologies combined with advertising for promising research fields may encourage future innovation (Moser and Nicholas, 2013). Incentives for R&D, such as grants and innovation prizes, could enhance innovation (Clancy and Moschini, 2013). Especially in capital-intensive industries, such as the pharmaceutical industry, innovation is strongly associated with prizes and government research, trying to address competition and bridge the gap between incentives and regulatory exclusivity provisions (Grabowski et.al. 2015). On the other hand, formal government enforcement of IPRs may be counterproductive. The prizes should consider the economic benefits of the market for inventions and contribute to the growth of economic efficiency in the context of

innovation. Market prizes could contribute towards this direction, as opposed to government prizes which incur a range of limitations (Spulber, 2014). Government grants should be considered on an ad hoc basis if firms want to benefit from patenting. Also, innovation can be seen through the prism of tax incentives, because the social-welfare costs in imperfect markets are reduced and taxpayers subsidise R&D costs, regardless of whether or not they are utilising the end product (Hemel and Larrimore Ouellette, 2013).

With respect to intellectual property rights, data collected from 94 countries within 40 years (1965-2005) verifies that IPRs have reinforced incentives to innovate, although stronger IPRs stimulate higher levels of economic complexity (Mehlig and Eterovic-Maggio, 2015). Moreover, IPR protection is stronger in firms that receive knowledge from abroad than in firms that transfer knowledge. According to studies employed on Korean firms, patent protection and IPRs represent important regulators of innovation and economic growth in the developed countries. Instead, in developing economies, protection of IPRs enhances firm performance and growth when firms lack technological knowledge to achieve innovation (Kim et al., 2012). Strengthening patent protection has an influence on economic growth, as stronger patent protection increases the profit flow of innovation but declines the factor demand for capital. Therefore, firms do not accumulate capital and one could argue that this negatively affects economic growth. On the other hand, in open economies, where technology and capital transfer takes place from abroad, strengthening the patent protection enhances technology adoption. Again, the difficulty in accumulating capital may impede economic growth (Iwaisako and Futagami, 2013). In the same context, evidence from the biomedical sector reveals that firms which desire to privatise biomedical research face the risk of overlapping IPRs due to high transaction costs, the conflicting interests of biomedical companies and the cognitive biases of researchers (Heller and Elsenberg, 1998).

A negative correlation has been identified between licensing and innovative performance. Firms that engage in licensing are more likely to experience fragmented intellectual property rights. Also, firms with fragmented IPRs are more likely to be engaging in licensing. Conversely, firms that do not license are found to have a higher innovative performance (Cockburn et al., 2010). Data derived from Japanese firms have

revealed a non-linear relationship between firm size and tendency to licensing. Smaller firms with restricted production facilities and marketing channels tend to license more, whereas larger firms benefit from the cross-licensing (Motohashi, 2008).[1] In European firms, the firm size figures as the governor of patent licensing, although other factors including patent value and patent protection could affect it. However, given that these factors determine the tendency to licensing, the fact that many potential licenses have not been licensed remains a concern (Gambardella et al., 2007). Also, firms may strategically choose not to make their patent claims to protect their IPRs (Bessen, and Meurer, 2006).

R&D-based growth could be achieved by targeting foreign direct investment and in domestic acquisitions. Firms that possess the know-how of R&D can implement the necessary strategies to succeed, even in highly knowledge-intensive industries (Stiebale, 2013). From this perspective, the transmission of technology is related to the level of Foreign Direct Investment (FDI) attractiveness in a country. Studies employed in Italy between 2010 and 2011 have illustrated a strong positive correlation between outward R&D and domestic R&D performed by foreign affiliates. More precisely, foreign multinationals are mostly active in cross-border R&D, but they maintain a low share of the market, whereas Italian firms do not aggressively invest in R&D abroad (Cozza and Zanfei, 2014). A positive spill over in the long-term on process innovation resulting from FDI was noticed in the Estonian manufacturing sector (Vahter, 2010). With respect to Greenfield FDI, a research study on Italian firms has highlighted a positive correlation between FDI and local patenting in knowledge-intensive business services (Antonietti, et al., 2015). FDI is also dependent upon managerial capabilities. Evidence derived from managers in multinational firms suggests that the more experienced they are, the more likely they are to employ internationalisation strategies, pursuing firm efficiency and innovation (Boermans and Roelfsema, 2013).

R&D intensity in cross-border strategic alliances is subject to the level of a firm's existing R&D capabilities and the valuation effect of their cross-border strategies (Owen and

[1] A cross-licensing agreement is an agreement between two or more licensees for the exchange of licenses so that both parties benefit from the other's patent. Usually, the patents that each party owns cover different aspects of a commercial product. Thus, by cross-licensing, each party maintains their freedom to bring the commercial product to market (US Legal, 2017).

Yawson, 2015). Usually, there is an asymmetry of impact on innovation between the acquirer and the target company due to variances in knowledge stocks (Stiebale, 2016). Cross-industry variability can occur due to cross-licensing and technology transfer with respect to the strength of IPRs (Anand and Khanna, 2000). Furthermore, technologies, patents, know-how and business processes can contribute to innovation in cross-industries. These skillsets have already been successfully employed by other industries, thus holding potential to meet the needs of firm's current market after adaptation (Enkel and Gassmann, 2010). In cross-industry innovation intermediaries play a vital role. Being external institutions, they could support the innovative activities of firms and help to bridge the gap between different industries (Gassmann et al., 2011).

Conclusively, one could argue that innovative start-ups are heavily engaging in R&D to stimulate new product development and achieve growth. In contrast, high-growth, well established firms view R&D as a part of their entrepreneurial policies. In addition, there are divergent models in technological innovation, especially in the economies that are transitioning towards innovation-based economies (Wang, 2007). These differences could be also justified by the role of innovation efforts in technological change in the emerging economies. Fu et.al, (2010) has argued that the benefits of technology diffusion could only be achieved if the economies are employing both indigenous and foreign innovation efforts in a complementary manner (Fu et.al, 2010). Also, firms need to engage in first-mover advantage and the street performer protocol strategies to protect their intellectual property rights. Hence, patent returns could be enhanced in the long-term, leading in turn to the firm's compensation for its R&D investment (Shughart and Thomas, 2015).

Chapter 3
Theoretical Background of Innovation and R&D

The concept of innovation has been analysed by many researchers and entrepreneurs as it explicitly contributes to firm growth and prosperity. In the modern business environment, access to information and development of knowledge are fundamentals for maintaining competitive advantage and achieving corporate success. In addition, the rise of e-learning and e-business as well as the transformation of information into knowledge are major factors for the survival of businesses. Hence, the creation of added value and long-term corporate success are both inextricably linked to a firm's ability to innovate.

3.1 The Macroeconomic Background

Today's sharing economy is mainly Information and Communications Technology (ICT)-driven and IP-oriented, with technology being a major factor of success of firms and products. The increasing significance of innovation practically drives companies to invest in R&D in order to become more competitive and enter new markets or sectors. Universities, specialised labs and research organisations are focusing more on industrialised and competitive products across all markets, including markets for labour, knowledge and financial services. Furthermore, the continuous development of in-house R&D provides companies with a growing market share, increasing specialisation and innovation diversification on a global scale.

Looking more closely to smaller firms, R&D encompasses various areas of development, aiming to integrate knowledge-based activities that could contribute to the firm's growth. Also, in terms of the required policies to foster R&D, there is still a lot of space for improvement, as there is no consensus as to which combination of policies could generate the optimum collective benefit. In this context, it seems that there is a gap of knowledge with respect to the adequate institutional framework (Braunerhjelm, 2012).

Innovation based on R&D is often encouraged by the patent system, especially in monopolistic markets. The interrelation between innovation and productivity is of major importance for those firms that desire to improve their current performance and launch products and services that can create increased consumer demand and efficiency gains in production (Hall, 2013). The newer economic theories consider patents as inventive for innovation and diffusion of knowledge; They promote the cooperation and the interaction of incentives to innovate in the context of property rights allocation and disclosure. Under this perspective, the role of government bodies and institutions should be to encourage and offer incentives (Granstrand, 2011) (Table 1).

Table 1. Newer economic perspectives on patents (Granstrand, 2011)

Patents as a joint incentive to innovate and diffuse	**Patent rights and patent information as a governance mechanism**
Focus: Impact on dynamic competition through "continuous" and entangled (interdependent) innovation and diffusion processes	*Focus: Property rights allocation and disclosure as a mode of incentivising and organising for decentralised governance through management hierarchies and markets*
Concerns:	Concerns:
• As for incentive-to-innovate	• Allocation and transfer of rights
• Efficiency/distortion of diffusion	• Accumulation and dispersion of rights
• Interdependence of inventions and innovations over time	• Interdependence of rights
• Dynamic interaction between innovation and diffusion	• Scope and duration of rights
	• Enforcement of rights
	• Governance efficiencies
	• Optimal decentralised tariffs or taxation
	• Role of governance bodies and institutions
	• Alternative governance mechanisms

In 2015, Global Innovation 1000 index that tracks the largest annual R&D spending across the 1,000 publicly-traded firms globally has increased 5.1% to $680 billion, indicating the largest Year over Year increase since 2012; 9.6%, from $560 billion in 2011 to $614 billion in 2012. Other significant rises in the annual R&D expenses have been noticed; While in 2007 the expenditure was calculated to 447 billion, a 12.1% rise was noticed leading to $501 billion in 2008, followed by a further 10.2% increase during 2010 to 2011, where the expenditure reached to $560 billion. Finally, the overall growth during the decade is 70.0%, starting from $400 billion in 2005 to $680 billion in 2015 (PwC, 2015) (Figure 1).

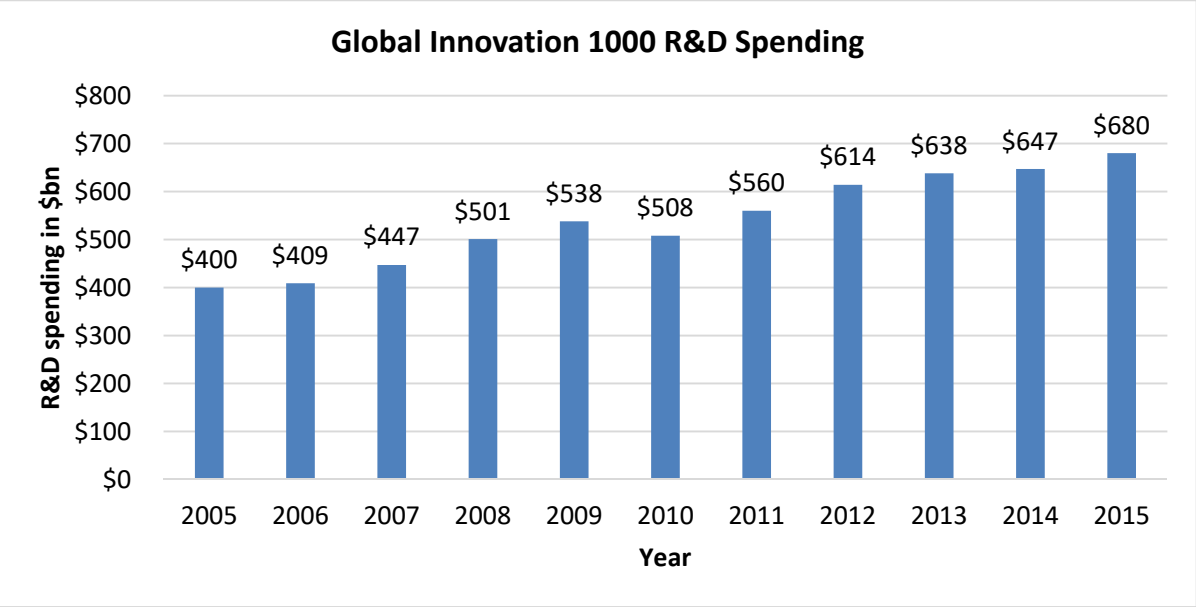


Figure 1. Global Innovation 1000 R&D Spending (2005-2015)

Source: https://www.strategyand.pwc.com/media/file/2015-Global-Innovation-1000-Fact-Pack.pdf

In 2016, on a global scale, the leading industries in R&D expenditure involved computing & electronics (24%), healthcare (22.1%) and auto (15.4%), followed by software & Internet (12.9%) and industrials (10.8%). On a smaller scale, chemicals & energy (5.5%), aerospace & defence (3.2%), consumer (3%), telecom (1.6%), and other (1.5%) complete the picture of R&D expenditure per industry (Statista, 2017) (Figure 2).

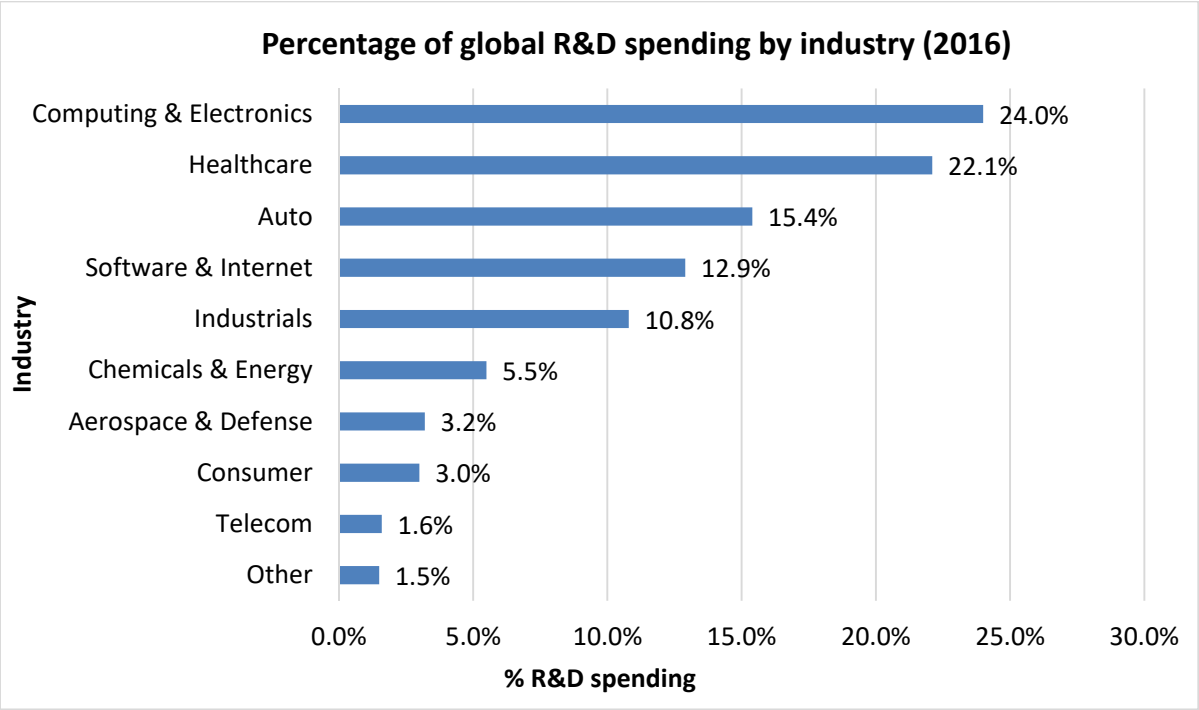


Figure 2. Percentage of global R&D spending by industry (2016)

Source: https://www.statista.com/statistics/270233/percentage-of-global-rundd-spending-by-industry/

3.2 Mechanisms for Innovation and Patents

Open innovation and knowledge represent a very promising tool for industry penetration and R&D intensity. Chesbrough et al. (2006) have defined open innovation as *"the use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation, respectively"*. Although open innovation was originally present in the high-tech industry, it has gradually expanded into new sectors to capitalise on market opportunities and pave the way for new inventions. Currently, R&D can be traced across different industries, including construction, manufacturing, medical equipment, food and consumer goods (Gassmann et. al., 2010).

Innovation is also affected by the firm structure. Open business models represent a concept of conducting business in a transparent way, by integrating an ecosystem of diverse participants who collaborate in public space. Central concepts to an open business model are sharing knowledge, open participation and community focus, which all aim to encourage the commercialisation of the ideas born within the circles of the

company as well as innovations adapted from other firms. In fact, according to Sawhney and co-workers (2006), 12 dimensions of business innovation can be detected based on the firm's offerings, customers, processes and overall market presence. These embody platform and solutions for the offerings, customer experience and value capture for the customers, organisation and supply chain for the processes as well as networking and brand for the firm's presence (Figure 3).

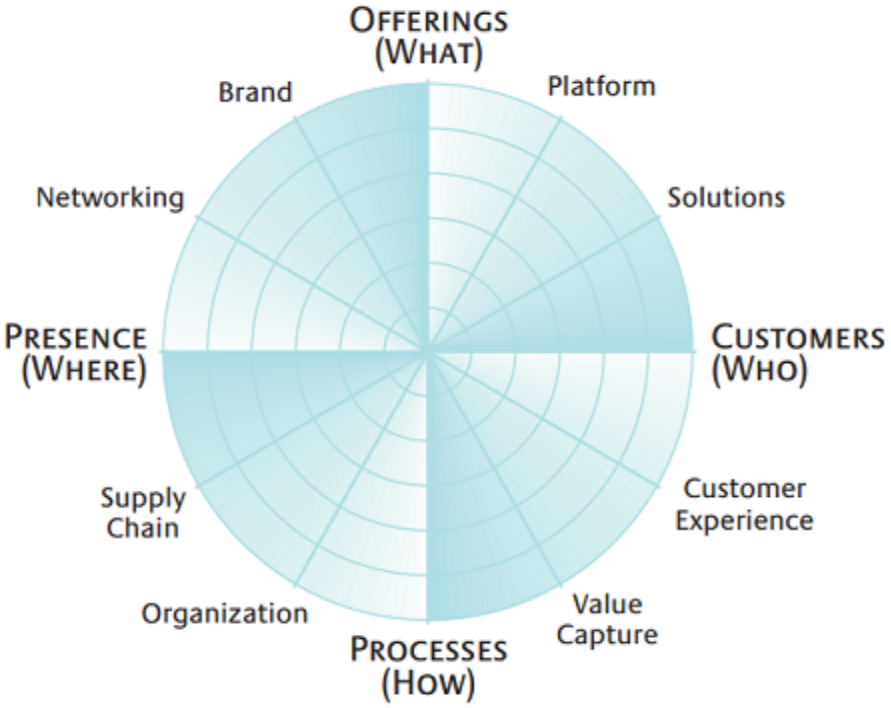


Figure 3. Dimensions of Business Innovation

Source: Sawhney et al. (2006:30)

Open business models allow firms for a smooth transition from their existing model to the new one. The presence of skilled workforce in the firm to support the process represents the main challenge and prerequisite though. To address this challenge, many companies continue investing in their internal processes, while implementing a new business model to reduce their costs and achieve market revenue (Chesbrough, 2007). The business model also determines the way of treating and protecting intellectual property. In closed-model firms, innovation occurs within the firm, whereas in open-model firms, innovation and knowledge derived from R&D are both diffused inside and outside of the firm (Figure 4) (Dasher, 2009).

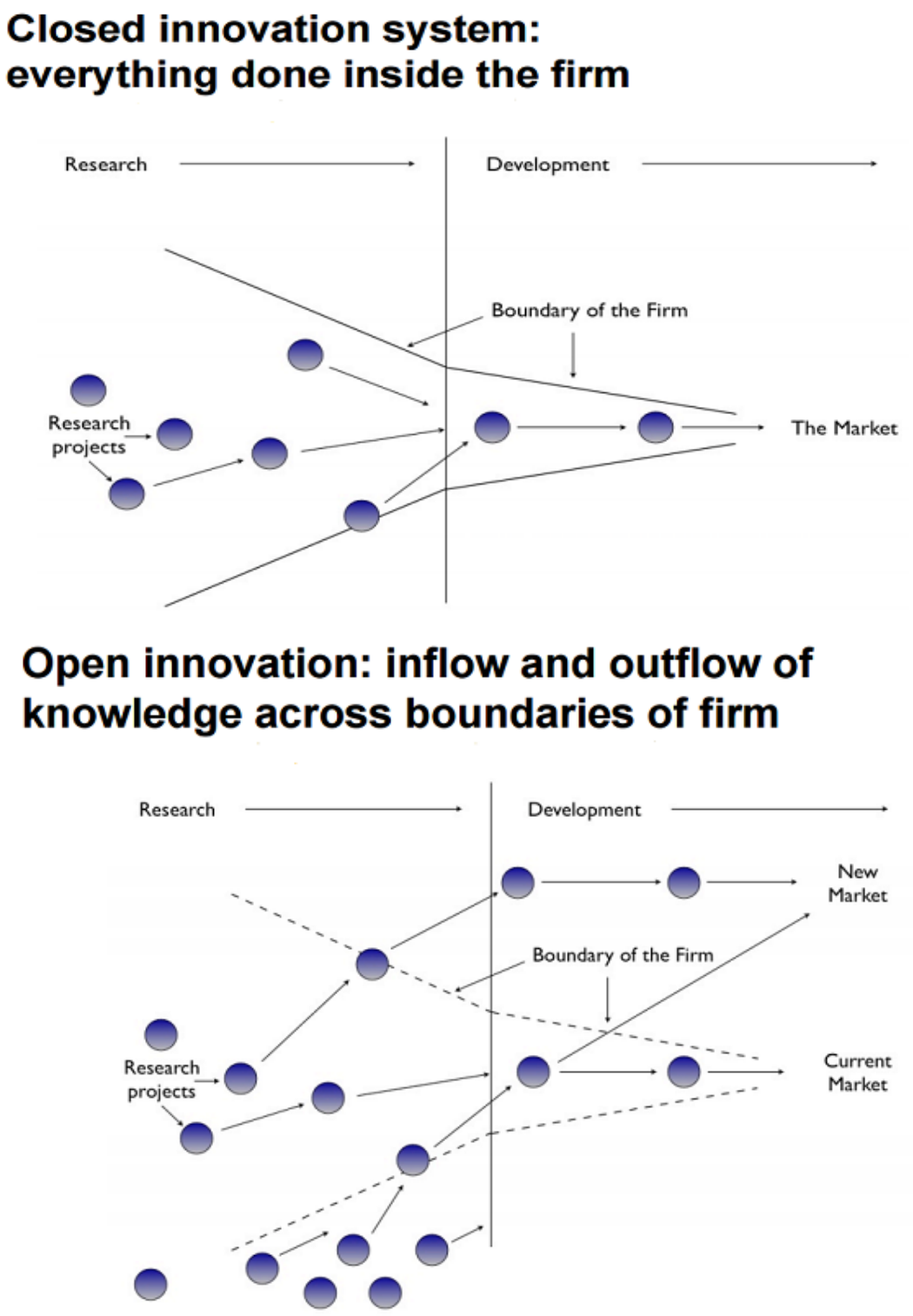


Figure 4. Closed and Open Innovation (Dasher, 2009)

Firm size is another key factor in a firm's decision to employ strategic choices related to innovation and R&D. Empirical evidence on 26 entrepreneurial SMEs confirms that larger firms are more likely to invest in R&D than small and medium-sized enterprises,

where the patent competence is low. However, smaller firms utilise patents to attract investors and venture capitalists, i.e. factors that are vital for the survival and growth of these firms (Holgersson, 2013). Smaller firms incur higher costs of R&D capital, which can only be alleviated with the presence of venture capital funding, whereas larger firms raise equity capital to fund their R&D investment (Djankov, et.al, 2009). In addition, innovation in corporately responsible companies is favoured through cooperation with external partners in an attempt to introduce environmental innovations and engage in R&D as a means to grow (De Marchi, 2012). On the other hand, in industries with high corporate taxation and a strong regulatory framework, the costs of entry are higher, thereby leading to fewer new firms and lower TFPs (total factor productivity) (Djankov, et.al., 2009).

The effect of patenting on R&D has also been investigated. A firm's decision to patent is subject to the recognition of the interrelation between R&D and patenting, although the extent of the effect varies across different industries and firm sizes (Arora et al., 2008). Studies employed on Italian firms have identified a strong and positive correlation between R&D and Information and Communication Technologies (ICTs), both contributing to innovation and productivity, especially in larger firms (Hall et al., 2013). Another study on 272 firms operating in 35 different industries over a 19 year period has concluded that firms, which heavily invest in R&D, are more likely to generate innovative output and increase returns to scale in innovation (Artz et al., 2010). A research on 781 manufacturing firms between 1998 and 2002 has demonstrated a strong correlation between R&D and product innovation, mainly in firms that collaborate with suppliers. Conversely, firms which collaborate with customers do not experience great benefits in product innovation, whereas collaborations with competitors seem to have a negative impact on product innovation. (Annique Un et al., 2010). Another study on the effects of patent protection on pharmaceutical innovations in 26 countries between 1978 and 2002 has revealed that national patent protection alone is not enough to stimulate innovation, but it should be combined with a higher level of economic development, education, and economic freedom. Yet, above an optimal level of IPRs regulation, innovation declines (Qian, 2007).

3.3 R&D Expenditures

R&D expenditures refer to short-term expenses that firms cannot cut back on immediately, but they can be reduced at a steady pace. R&D expenditures include patent expenses as well, which refer to long-term costs, which incur a certain level of risk for the firm's assets and can be reduced at a slower pace. Therefore, a firm's decision to patent its R&D activity, especially under the current strained financial environment of most economies due to the economic crisis, represents a strategic decision. A firm needs to determine what inventions to patent, considering the strengths of competitive firms and the number of potential customers. In the current volatile financial environment, the stimulus to innovate is highly correlated to the achievement of a firm's long-term goals and entrance in global markets. Hence, the choice of countries to apply for patent should be based upon the market's prospects to recover after the crisis. However, although the tendency to patent is correlated to a firm's intention to protect its intellectual property rights, only 15% of firms actually patent their R&D and innovation activities due to high costs and financial liabilities (Bessen and Meurer, 2006).

3.4 Innovation and R&D in Greece

R&D can help the Greek firms to become more competitive by integrating new technologies and R&D investment in their core processes as part of their strategic motivation (Manolopoulos et.al. 2007). A direct relationship between external knowledge inflows and the absorptive capacity of the company has been highlghted when 461 Greek enterprises have been investigated, suggesting that the absorptive capacity can contribute to innovation and improve financial performance (Kostopoulos et. al., 2011). Yet, many asymmetries in the policy framework for innovation have been noticed, which inevitably lead to failures. The irregularities of the government technology and innovation policy have forced companies to contract their R&D investment, thereby being positioned lower than their European peers (Komninos and Tsamis, 2008). According to Organization for Economic Cooperation and Development (OECD), Greece is positioned lower than the World total and significantly lower than the

EU-27 and the OECD countries. Also, stronger economies with a higher specialisation in ICT-driven initiatives tend to turn more to patents rather than trademarks, whereas economies with a larger services sector tend to engage more in trademark than patent protection (OECD, 2011) (Figure 5).

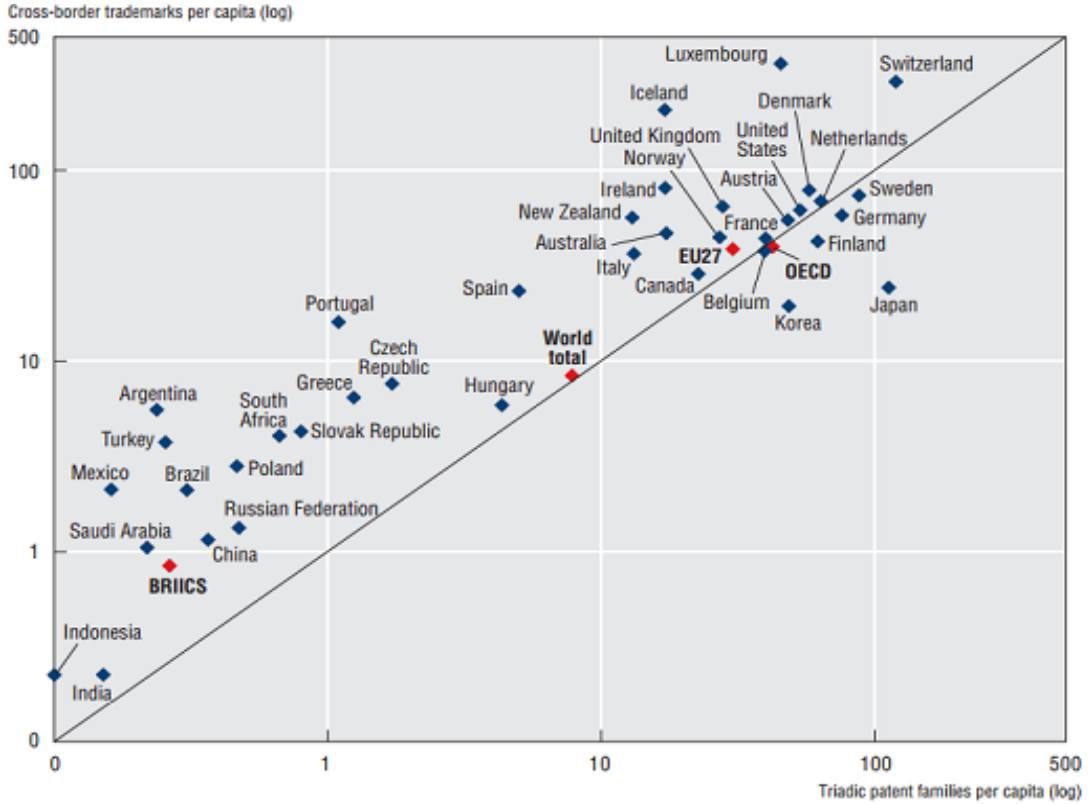


Figure 5. Average No. of patents per million population, OECD, and G20 countries (2005-2007) *Source: OECD*

Intrestingly, in 2016, Greece has improved its position on the Global Innovation Index, being ranked in the 40th position out of 128 countries with a score 39.8 and an efficiency ratio 0.61. The ranking was higher than 2015 (45th position), whereas in the Innovation Input Sub-Index, the country was ranked in the 37th position (Global Innovation Index, 2016). Technological progress is a major component of long-term economic growth, as it addresses the capacity of industrial and newly industrialised countries to convert their technological capacity into productivity. Typically, the main measurement for the aggregate expenditure on R&D is the R&D as a percentage of GDP, which covers all R&D-related spending of an economy during a given year. Thus, it includes domestically-performed R&D financed from abroad, but it excludes R&D expenditures for foreign R&D projects (Korres and Drakopoulos. 2009). With respect to

the gross domestic R&D expenditure in 2015, Greece was ranked in the 39th position out of 128 countries with a percent rank 0.64 (Global Innovation Index, 2016); whereas in 2014, the gross domestic R&D expenditure in Greece accounted for 83.5% of the GDP. Nevertheless, the country still ranks low in the EU-28 list (OECD, 2017) (Figure 6).

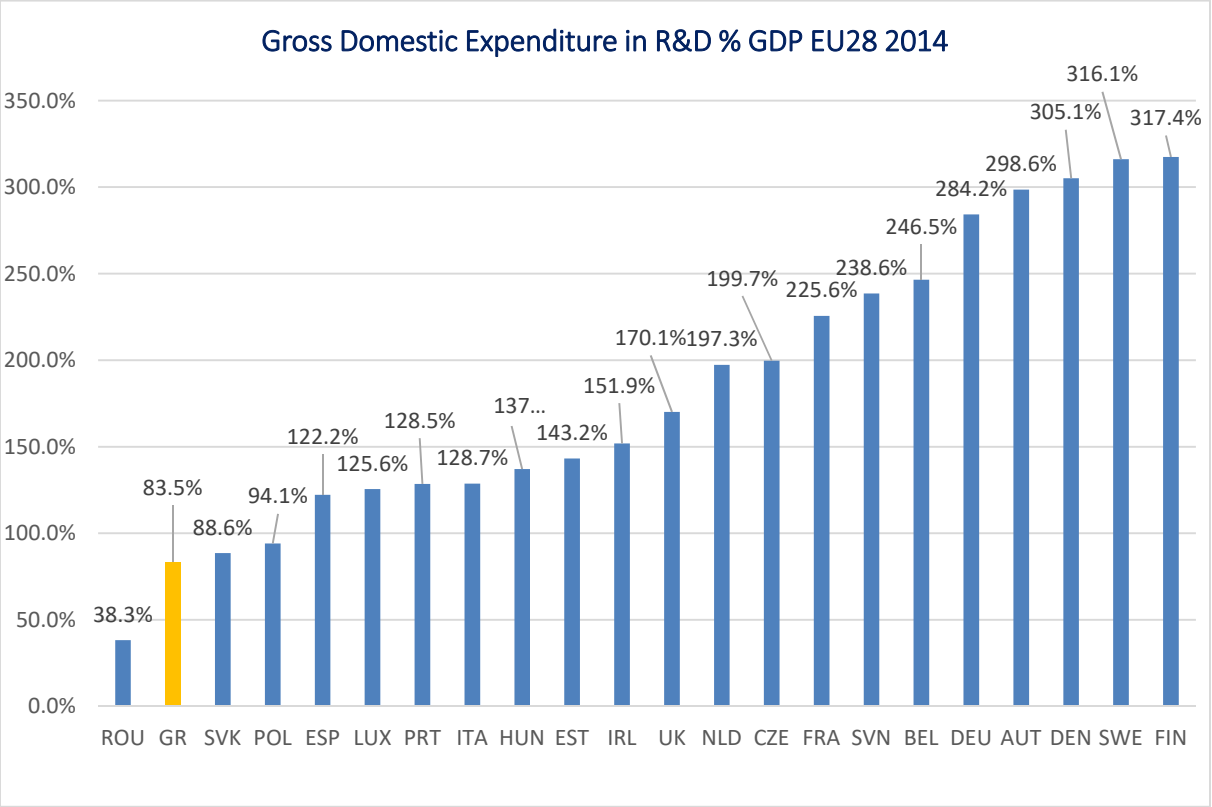


Figure 6. Gross Domestic Expenditure in R&D % GDP EU28 2014

Source: http://www.oecd.org/innovation/inno/researchanddevelopmentstatisticsrds.htm

In 2013, gross domestic expenditure in R&D reached $2.14 billion, up 12.4% from $1.90 billion in 2012 and 8.5% from $1.97 billion in 2011. Remarkably, the greatest share of government R&D is towards culture, recreation, religion, and mass media with $208.2 million in 2013, up 84.5% from $.112.9 million in 2011. A significant increase of 56.4% is recorded in health R&D expenditure, from $81.2 million in 2011 to $127.01 million in 2013. Conversely, the environment and transport (infrastructure) sectors have experienced a drop in R&D expenditure from 2011 to 2013 by -40.4% and -37.6% respectively. While R&D expenditure on the business enterprise sector has climbed from $651.2 million in 2012 to $711.9 million in 2013, on higher education sector it has augmented by 5.4% from $758.7 million in 2012 to $799.3 million in 2013. Finally, the

R&D costs of the private non-profit sector have expressed a surprising surge of 46.3%, being $18.2 million in 2012 and $26.6 million in 2013 (Table 2).

Table 2. Gross domestic expenditure on R-D by sector and objective ($ml)

Sector	Socioeconomic Objective	2011	2012	2013
Government	Exploration and exploitation of the Earth	55.63		54.82
	Environment	34.39		20.50
	Exploration and exploitation of space	5.38		4.91
	Transport, telecommunication and other infrastructures	36.50		22.79
	Energy	22.21		29.65
	Industrial Production and technology	11.88		19.73
	Health	81.20		127.01
	Agriculture	25.04		31.22
	Education	15.56		21.45
	Culture, recreation, religion and mass media	112.89		208.25
	Political and social systems, structures and processes	10.47		12.62
	General advancement of knowledge	55.46		42.91
	Defence	2.69		1.68
	Total	**469.29**	**471.27**	**597.53**
Business Enterprise	**Total**	**687.33**	**651.18**	**711.98**
Higher education	**Total**	**791.55**	**758.67**	**799.27**
Private non-profit	**Total**	**19.86**	**18.18**	**26.59**
Total intramural	**Total**	**1,968**	**1,899**	**2,135**

Source: *https://stats.oecd.org/Index.aspx?DataSetCode=BERD_INDUSTRY#*

There results illustrate that despite the ongoing financial crisis and its impact across many sectors of the Greek economy, the Greek firms engage in innovation and seek growth through R&D. However, the main question remains whether the Greek companies are prepared to withstand the economic crisis. Although management capacity in the Greek private sector seems to be effective, Greek firms, in majority, do not possess a strong competitive position in the international value chains and operate on quite simple business models. Meanwhile, the Greek firms are facing a negative regulatory and institutional environment, perhaps the worst in the European Union, which has created sectoral distortions, reluctance on new entrants and a situation of low productivity and maintenance of the status quo. On the other hand, there are several business sectors in Greece that have demonstrated exceptional levels of competitiveness, continuous innovation and international expansion, such as new technology sectors with international critical mass; manufacturing industries with innovative and internationally recognised industrial products such as the Greek

aluminium industry and food retailing. These industries offer best practices to imitate and have increased chances to survive under certain institutional conditions and strategies.

Chapter 4
Data Analysis

In this chapter, the study performs a comparative analysis of R&D spending in selected countries, i.e. Germany, Greece, the United Kingdom and the United States as well as on patent activity in the OECD countries, including those mentioned above.

4.1 Gross Domestic Expenditure on R&D (GERD)

The first indicator with respect to R&D is the gross domestic expenditure as a percentage of GDP. Gross domestic spending on R&D is defined as the sum of the current and capital expenditure on R&D carried out in a country by research institutes, university and government laboratories as well as domestic companies. Gross domestic expenditure on R&D includes R&D activities that are funded from abroad, but not R&D performed abroad and funded by domestic funds (OECD, 2017b).

The average gross domestic expenditure on R&D in the OECD countries for the period 2000 – 2015 was 225.2%, which stands higher than the average in the UK (163.8%) and in Greece (65.8%). In contrast, the average gross domestic expenditure on R&D in Germany was 260.5% and in the US 266.4% (Table 3).

Table 3. Gross Domestic Expenditure on R&D % GDP (2000-2015)

YEAR	DEU	GRC	UK	USA	OECD
2000	239.2%		163.9%	262.1%	213.3%
2001	238.6%	55.9%	163.2%	263.8%	217.1%
2002	241.5%		164.0%	255.0%	214.5%
2003	245.7%	54.7%	160.2%	255.3%	214.8%
2004	242.1%	52.7%	155.2%	249.0%	212.1%
2005	242.3%	57.9%	157.2%	250.6%	215.2%
2006	245.6%	56.1%	159.4%	255.0%	218.3%
2007	244.6%	57.7%	163.3%	262.7%	221.8%
2008	259.7%	66.2%	163.9%	276.7%	229.0%
2009	272.6%	62.6%	170.2%	281.9%	233.7%
2010	271.4%	59.8%	167.7%	274.0%	229.9%
2011	279.6%	67.2%	168.2%	277.0%	233.3%
2012	286.8%	70.0%	161.2%	270.6%	233.8%
2013	282.1%	81.1%	166.0%	274.2%	236.7%
2014	288.8%	83.7%	167.9%	275.6%	239.5%
2015	287.5%	95.8%	170.1%	278.8%	240.3%
Average	***260.5%***	***65.8%***	***163.8%***	***266.4%***	***225.2%***

Source: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm#indicator-chart

While in Germany the R&D expenditure between 2004 and 2009 has shown a significant raise (11.2%), climbing from 242.1% to 272.6%, the costs in the UK have increased by 8.8%, from 155.2% to 170.2%, whereas in the United States a percentage of 11.7% has lead the R&D spending from 249.0% in 2004 to 281.9% in 2009 (Table 4-1). The same trend was noticed in the OECD countries, in which an increase of 9.2% is noted between 2004 and 2009 from 212.1% to 233.7%,

By monitoring the performance of Greece between 2003 and 2015, minor fluctuations could be observed. For example, a decrease of -3.6% was noticed between 2003 and 2004 from 54.7% to 52.7%, followed by a noticeable rise of 8.9% from 52.7% to 57.9% in 2005, declining afterwards by -3.2% from 57.9% to 56.1% in 2006; then the remarkable increase of 15.2% to 66.2% in 2008 was shadowed by a decrease of -10.6% in 2010. Nonetheless, the trend was upward from 2010 to 2015, with a significant increase of 33.4% from 59.8% to 95.8% (Figure 7).

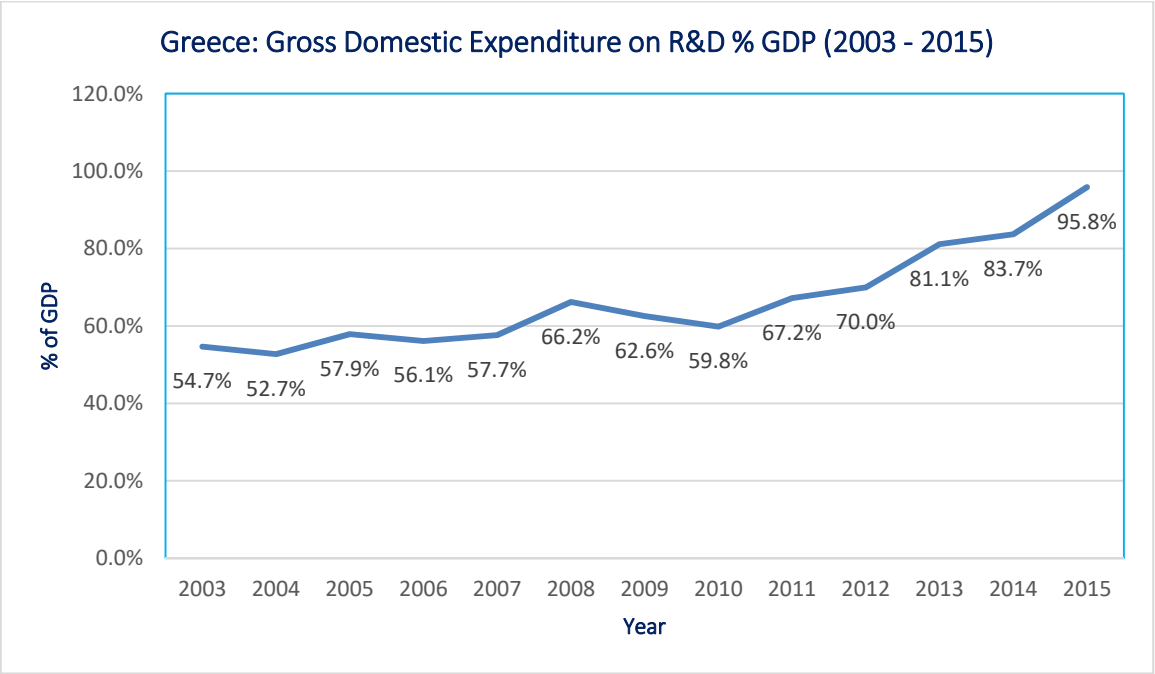


Figure 7. Greece: Gross Domestic Expenditure on R&D % GDP (2003 - 2015)

Source: *https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm#indicator-chart*

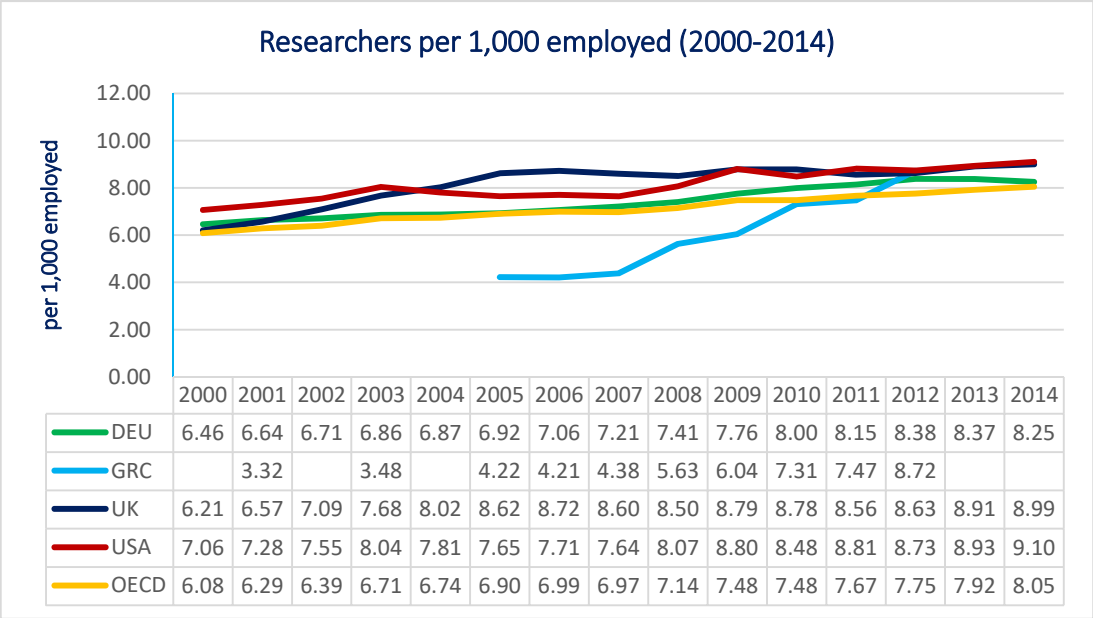
4.2 Researchers

Researchers are professionals who aim to create new knowledge, products, methods, approaches and structures. According to the European Commission and the European Parliament, Europe should become "a more attractive place to conduct research activities" with the implementation of an integrated framework of researcher support policies (European Union, 2009:82).

Researchers per 1,000 employed in the OECD countries have increased by 32.4% from 6.08 people in 2000 to 8.05 people in 2014, while in the US and in Germany the percentages have been accounted to 28.8% and 27.7%, from 7.06 and 6.46 people in 2000 to 9.10 and 8.25 people in 2014 respectively. The same trend was shown in the UK, where the percentage of researchers per 1,000 employed augmented by 44.9%, from 6.21 to 8.99 people between 2000 and 2004, whereas in Greece there was a sharp surge of 106.9% between 2005 and 2012, from 4.22 people to 8.72 people in 2012 (Figure 8).

The most remarkable fluctuations in the countries of interest except from Greece are summarised below: in Germany, the number of people was increased 4.5%, from 7.41 to

7.76 between 2008 and 2009; in the UK the percentage of upsurge was calculated to 6.9%, being 8.02 people in 2004 and 8.62 people in 2005; in the US the rise of the percentage was even larger, reaching at 8.4% within 2008 and 2009, counting for 8.07 and 8.80 people respectively; in the OECD countries, while in 2002 people were 6.39, they were found to be 6.71 in 2003, expressing an increase of 4.8%.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DEU	6.46	6.64	6.71	6.86	6.87	6.92	7.06	7.21	7.41	7.76	8.00	8.15	8.38	8.37	8.25
GRC		3.32		3.48		4.22	4.21	4.38	5.63	6.04	7.31	7.47	8.72		
UK	6.21	6.57	7.09	7.68	8.02	8.62	8.72	8.60	8.50	8.79	8.78	8.56	8.63	8.91	8.99
USA	7.06	7.28	7.55	8.04	7.81	7.65	7.71	7.64	8.07	8.80	8.48	8.81	8.73	8.93	9.10
OECD	6.08	6.29	6.39	6.71	6.74	6.90	6.99	6.97	7.14	7.48	7.48	7.67	7.75	7.92	8.05

Figure 8. Researchers per 1,000 employed (2000-2014)

Source: https://data.oecd.org/rd/researchers.htm#indicator-chart

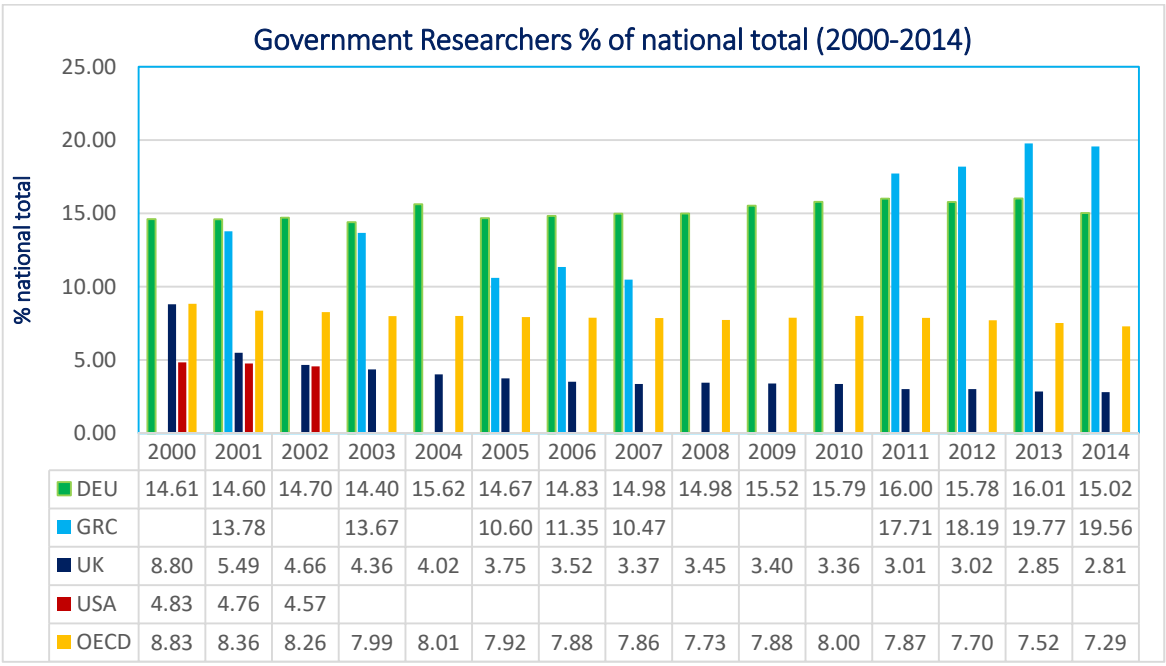
By monitoring Greece, a few notable fluctuations could be observed, including: a sharp surge of the number of people by 22.2% between 2007 and 2008, from 4.38 to 5.63 people; the percentage of peoples' increase was calculated to 17.4% between 2009 and 2010, mirroring 6.04 and 7.31 people respectively. Finally, while in 2011 people were counting for 7.47, they were found to be 8.72 in 2012, expressing a raise by 14.4%.

4.3 Government Researchers

Government researchers are professionals who work in governmental institutions, seeking to produce new knowledge, products, methods, approaches and structures (OECD, 2017c).

Government researchers in the OECD countries decreased by -17.5% from 8.83 people in 2000 to 7.29 people in 2014. More precisely, in the UK a significant drop (-68.1%) was observed in the amount of people since 2000, where they counted for 8.80, being 2.81 people in 2014, whereas no data is available for the United States after 2002. Conversely, government researchers increased in Germany by 2.80% between the years 2000 and 2014 from 14.61 to 15.02 people respectively as well as in Greece, where in 2011 people accounted for 17.71 as opposed to 2014, in which their amount raised by 10.4%, being 19.56 people in total (Figure 9).

Despite the overall increase, Germany incurred a significant decline of -6.5% in 2005, from 15.62 people in 2004 to 14.67 people in 2005 and of -6.6% in 2014 from 16.01 people in 2013 to15.02 people in 2014. The sharpest decrease (-60.3%) was noted in the UK in 2001, with people being 8.80 in 2000 and reaching their lowest peak in 2001, counting for only 5.49 people. In the OECD countries, the percentage of people has fallen by almost -10% between 2000 and 2003, from 8.83 to 7.99 people respectively.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DEU	14.61	14.60	14.70	14.40	15.62	14.67	14.83	14.98	14.98	15.52	15.79	16.00	15.78	16.01	15.02
GRC		13.78		13.67		10.60	11.35	10.47				17.71	18.19	19.77	19.56
UK	8.80	5.49	4.66	4.36	4.02	3.75	3.52	3.37	3.45	3.40	3.36	3.01	3.02	2.85	2.81
USA	4.83	4.76	4.57												
OECD	8.83	8.36	8.26	7.99	8.01	7.92	7.88	7.86	7.73	7.88	8.00	7.87	7.70	7.52	7.29

Figure 9. Government Researchers % of national total (2000-2014)

Source: https://data.oecd.org/rd/government-researchers.htm#indicator-chart

4.4 Triadic Patent Families

Triadic patent families are sets of patents registered in patent offices in various countries to protect the same invention and they are filled at the European Patent Office (EPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO). In addition, a triadic patent family is attributed to the country of residence of the inventor and to the date that it was originally registered (OECD, 2017d).

The OECD in total, declined -7.2% between 2000 and 2014, from 54,904.25 50,948.42 patents respectively. Germany accounts for 10.9% of the total OECD on average with the percentage of the patents being decreased by -41.0% within this period of time, from 7,638.86 patents in 2000 to 4,509.40 patents in 2014. Meanwhile, in the US, which represents 27.4% of the total OECD on average, patents have dropped by -4.4%, from 15,624.25 patents in 2000 to 14,943.86 in 2014. In the UK, which constitutes a smaller portion the total OECD (3.6%), the patents declined by -23.5%, from 2,361.89 in 2000 to 1,807.77 in 2014. On the other hand, in Greece, patents increased by 138.2% between 2000 and 2014 from 10.98 to 26.14 patents respectively; however, the country accounts only for 0.03% of the total OECD (Table 4. Triadic Patent Families (2000-2014)Table 4).

Table 4. Triadic Patent Families (2000-2014)

YEAR	DEU	% OECD	GRC	% OECD	UK	% OECD	USA	% OECD	OECD
2000	7,638.86	13.91%	10.98	0.02%	2,361.89	4.30%	15,624.25	28.46%	54,904.25
2001	7,231.61	13.17%	11.63	0.02%	2,293.04	4.18%	15,903.53	28.97%	53,615.07
2002	6,882.98	12.54%	12.01	0.02%	2,223.61	4.05%	16,451.83	29.96%	54,886.03
2003	6,742.60	12.28%	20.44	0.04%	2,196.89	4.00%	16,749.90	30.51%	56,930.42
2004	6,994.49	12.74%	14.87	0.03%	2,095.12	3.82%	17,202.35	31.33%	59,571.16
2005	7,139.02	13.00%	24.02	0.04%	2,159.88	3.93%	17,375.62	31.65%	59,246.63
2006	6,531.57	11.90%	22.02	0.04%	2,091.38	3.81%	15,463.32	28.16%	55,336.04
2007	5,807.09	10.58%	13.92	0.03%	1,801.41	3.28%	13,891.39	25.30%	51,331.33
2008	5,471.18	9.96%	16.08	0.03%	1,698.41	3.09%	13,818.55	25.17%	48,966.81
2009	5,554.59	10.12%	15.45	0.03%	1,723.01	3.14%	13,498.77	24.59%	49,163.58
2010	5,058.66	9.21%	5.33	0.01%	1,657.38	3.02%	12,744.96	23.21%	49,193.07
2011	4,804.38	8.75%	10.62	0.02%	1,726.71	3.14%	13,176.16	24.00%	49,566.82
2012	4,611.94	8.40%	22.44	0.04%	1,714.91	3.12%	13,785.04	25.11%	49,843.14
2013	4,573.22	8.33%	22.90	0.04%	1,792.01	3.26%	14,687.96	26.75%	50,501.90
2014	4,509.40	8.21%	26.14	0.05%	1,807.77	3.29%	14,943.86	27.22%	50,948.42
Δ	***-41.0%***	***10.9%***	***138.2%***	***0.03%***	***-23.5%***	***3.6%***	***-4.4%***	***27.4%***	***-7.2%***

Source: *https://data.oecd.org/rd/triadic-patent-families.htm#indicator-chart*

Although triadic patent families in Greece have surged within these fourteen years, extreme fluctuations have been observed in between. For example, a sharp rise of 41.2% in 2003, from 12.01 patents in 2002 to 20.44 patents in 2003, followed by a remarkable decline of -37.5% to 14.87 patents in 2004; a surprising increase of 38.1% to 24.02 patents next year followed again by a significant decrease of -42.1% to 13.92 patents in 2007; an upsurge of 13.5% to 16.08 patents in 2008 turned into a sharp reduction of -66.8% to 5.33 patents in 2010 and finally an increase of 390.2% to reach the highest peak of 26.14 patents in 2014 (Figure 10). In contrast, Germany, the UK, the US and the OECD countries have not experienced any great variance in the number of patents (Figure 10).

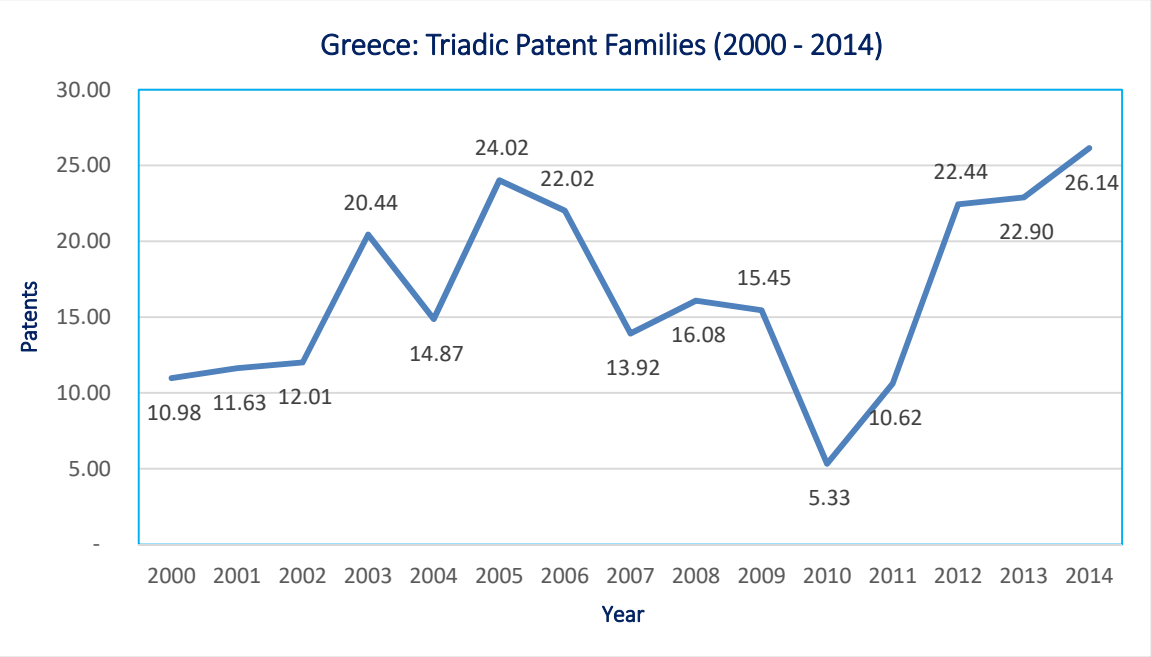


Figure 10. Greece: Triadic Patent Families (2000 - 2014)

Source: *https://data.oecd.org/rd/triadic-patent-families.htm#indicator-chart*

Conclusively, gross domestic expenditure on R&D % GDP in Greece presents an upward trend with no sharp fluctuations, ranging between 54.7% and 95.8% from 2003 to 2015. The upward trend is also noticed in the researchers and government researchers that have increased by 106.9% and 10.4%, respectively, with no significant fluctuations in between. On the other hand, extreme fluctuations have been reported in the triadic patents families; therefore, no particular trend can be identified.

Chapter 5
Empirical Analysis

Different indicators are utilised for the measurement of the internationalisation of R&D and innovation activities. Most notably, OECD takes into account the cross-border ownership of inventions which are classified as foreign ownership of domestic inventions and domestic ownership of inventions made abroad, filled under the USPTO and the EPO. The United States Patent and Trademark Office (USPTO) is responsible for the granting of patents to protect inventions and register trademarks to the best interest of inventors and businesses. In addition, USPTO has an advisory role to the U.S. President, the Secretary of Commerce, the Department of Commerce and any other agency that pertains to the protection of intellectual property (USPTO, 2017). Similarly, the European Patent Office is responsible for supporting innovation, competitiveness and economic growth in the European countries (EPO, 2017).

5.1 Cross-border ownership of inventions

Cross-border ownership occurs when the inventor's country of residence is different than the applicant's country of residence. In this case, the information of the patent can be obtained either directly or indirectly by the patent documents and two indicators are typically measured on a country or regional level: a) *Foreign ownership of domestic inventions (FODI)*, which refers to the number of patents which are granted to applicants residing abroad and b) *Domestic ownership of inventions made abroad (DOMA)*, which refers to the number of patents granted to a country and have been made abroad from at least one foreign inventor (OECD, 2009). The indicator of foreign ownership of domestic inventions reflects the extent of foreign control on domestic inventions.[2] The indicator

[2] Foreign control means that the economic benefits arising from the inventions are shared between the country of invention, the country of ownership, but also partly other countries, as multinational companies may implement part of their manufacturing or sales technology worldwide (OECD, 2009:127).

of domestic ownership of inventions made abroad expresses the extent of domestic control to inventions made by residents of foreign countries. Both indicators are essential when assessing the complementary role of foreign affiliates of multinational firms in innovation activities.

5.1.1 Foreign ownership of domestic inventions under the USPTO

The foreign ownership of domestic inventions in patents granted by the USPTO in the OECD countries increased 18.6%, from 270,147 patents in 2000 to 320,455 patents in 2013. The sharpest increase was noted between 2000 and 2006, being 27.9%, from 270,147 patents in 2000 to 345,476 patents in 2006, and the sharpest decrease -10.7% was observed between 2006 and 2009, from 345,476 to 308,582 patents respectively. In Germany, the number of foreign ownership of domestic inventions under the USPTO reduced by -16.4% from 20,203 patents in 2000 to 16,886 patents in 2013. The most significant rise (11.7%) was reported between 2000 and 2004, from 20,203 patents in 2000 to 22,562 patents in 2004, while the lowest peak was reached in 2013, patents being -19.9% declined compared to 21,075 patents in 2012. In the UK, the number of foreign ownership of domestic inventions granted by the USPTO dropped by -16.3%, from 9,345 patents in 2000 to 7,820 patents in 2013. Although the most remarkable upsurge (7.4%) was noticed between 2004 and 2006, when the patents were 8,842 and 9,493 respectively, patents fell from 9,175 in 2011 to 7,820 patents in 2013 (-14.8%). Unlike Germany and the UK, the number of foreign ownership of domestic inventions under the USPTO in the US showed an upward trend, augmenting by 16.1%, being 142,306 patents in 2000 and 165,243 patents in 2013. The most noticeable raise (15.6%) occurred between 2000 and 2002, from 142,306 patents in 2000 to 164,491 patents in 2002, whereas the sharpest decrease (-15.4%) was noted between 2006 and in 2009, from 173,368 patents in 2006 to 146,621 patents in 2009 (Table 5).

Table 5. Number of foreign ownership of domestic inventions, USPTO (2000 – 2013)

	DEU	GRC	UK	USA	OECD
2000	20,203	70	9,345	142,306	270,147
2001	**20,783**	**75**	**9,699**	**159,033**	**294,451**
2002	20,740	109	9,143	164,491	306,975
2003	20,873	118	9,246	164,068	315,422
2004	22,562	113	8,842	169,069	331,724
2005	22,539	150	9,064	173,070	344,024
2006	22,206	128	9,493	173,368	345,476
2007	22,102	161	9,239	172,193	344,685
2008	21,068	153	8,989	160,855	327,041
2009	20,422	147	8,713	146,621	308,582
2010	21,109	114	8,847	150,497	322,906
2011	20,825	121	9,175	156,682	331,138
2012	21,075	167	9,025	167,714	346,980
2013	16,886	150	7,820	165,243	320,455
Δ	***-16.4%***	***114.3%***	***-16.3%***	***16.1%***	***18.6%***

Source: *http://stats.oecd.org/Index.aspx?QueryId=22021*

In Greece, number of foreign ownership of domestic inventions in patents granted by the USPTO increased by 114.3%, from 70 patents in 2000 to 150 patents in 2013. Following the same pattern as in the gross domestic spending on R&D as a percentage of GDP and in triadic patent families, the number of patents in Greece showed high variability. A sharp surge of 68.6% happened between 2000 and 2002, from 70 patents in 2000 to 118 patents in 2003; an increase by 32.73% in 2005, from 113 patents in 2004 to 150 patents in 2005; a decrease of -14.7% to 128 patents in 2006; a rise by 25.8% to 161 patents in 2007; a decline of -29.2% between 2007 and 2010, from 161 patents in 2007 to 114 patents in 2010; an upturn by 46.5% between 2010 and 2012, from 114 patents in 2010 to 167 patents in 2012 and finally, a reduction by -10.2% to 150 patents in 2013 (Figure 11).

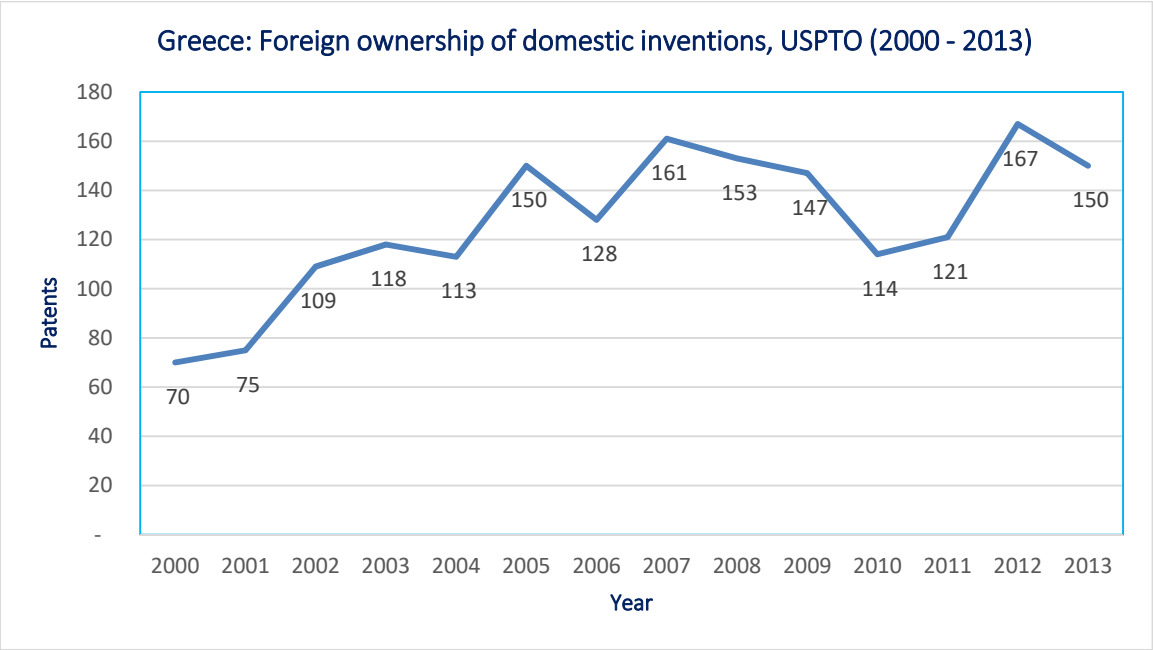


Figure 11. Greece: Foreign ownership of domestic inventions, USPTO (2000 – 2013)

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

5.1.2 Foreign ownership of domestic inventions under the EPO

The foreign ownership of domestic inventions in patents granted by the EPO in the OECD countries has increased by 22.6% overall, from 115,057 patents in 2000 to 141,076 patents in 2013. The most interesting growth by 63.5% was described in 2012, from 84,512 patents in 2011 to 138,142 patents in 2012, whereas the lowest peak was reached in 2011 (-35.9%), from 131,787 patents in 2005 to 84,512 patents in 2011. In Germany, the number of foreign ownership of domestic inventions in patents granted by the EPO decreased by -0.9%, from 23,564 patents in 2000 to 23,363 patents in 2013. Within the next 7 years though, the number of patents has augmented again, from 23,368 patents in 2001 to 26,504 patents in 2007, followed by the most significant decline (-11.9%) from 26,504 patents in 2007 to 23,363 patents in 2013. Data also have proven that the patents in the UK showed a slight decrease between 2000 and 2013, 6,952 patents being the starting point and 6,714 their final value, while the lowest peak (-8.4%) was monitored during the last half of this period, from 6,904 patents in 2006 to 6,327 patents in 2012, followed by the highest for the country percentage of growth (6.1%) resulting in 6,714 patents in 2013. In the US, the number of foreign ownership of domestic inventions under the EPO increased 18.2%, from 34,238 patents in 2000 to

40,457 patents in 2013. The most significant increase (22.9%) was noted between 2009 and 2013, from 32,913 patents in 2009 to 40,457 patents in 2013, whereas the sharpest decrease -18.3% was noticed between 2005 and 2009, from 40,296 patents in 2005 to 32,913 patents in 2009 (Table 6).

Table 6. Foreign ownership of domestic inventions in patents, EPO (2000 – 2013)

	DEU	GRC	UK	USA	OECD
2000	23,564	74	6,952	34,238	115,057
2001	23,368	87	6,603	33,911	113,078
2002	23,421	100	6,560	35,579	116,134
2003	23,827	108	6,596	36,658	121,060
2004	24,915	84	6,676	38,596	128,305
2005	25,967	134	6,743	40,296	131,787
2006	26,090	120	6,904	37,959	130,321
2007	26,504	131	6,834	35,301	126,714
2008	25,095	109	6,422	33,606	127,641
2009	25,368	121	6,426	32,913	120,626
2010	25,328	90	6,330	33,168	123,181
2011	24,846	101	6,452	35,356	84,512
2012	23,827	129	6,327	37,029	138,142
2013	23,363	127	6,714	40,457	141,076
Δ	***-0.9%***	***71.6%***	***-3.4%***	***18.2%***	***22.6%***

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

In Greece, the number of foreign ownership of domestic inventions under the EPO has raised by 71.6%, counting for 74 patents in 2000 and 127 patents in 2013. However, many fluctuations have been observed during this time period. Despite the upward trend between 2000 and 2003 that an increase of 49.5% was calculated and the patents counted for 108, in 2004 the number of patents reached the lowest point (-22.2%) within a period of thirteen years, being 84 in total in 2004. The pattern observed during the next years was similar; a surge by 59.5% to 134 patents in 2005 followed by a decrease -10.4% to 120 patents the next year; an increase by 9.2% to 131 patents in 2007 which was afterwards reduced by -16.8% to 109 patents in 2008; a rise by 11.0% to 121 patents in 2009 followed by a decline -25.6% to 90 patents after a year, an increase by 43.3% between 2010 and 2012, from 90 patents in 2010 to 129 patents in 2012 and finally, a decrease -1.6% to 127 patents in 2013 (Figure 12).

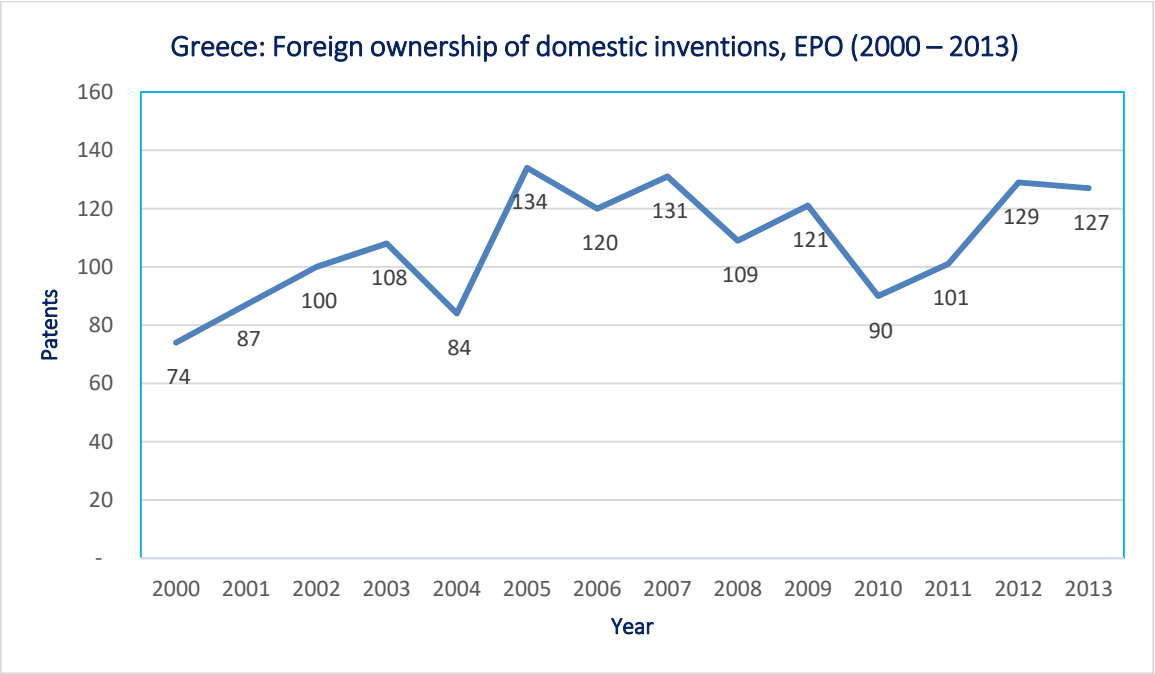


Figure 12. Greece: Foreign ownership of domestic inventions, EPO (2000 – 2013)

Source: *http://stats.oecd.org/Index.aspx?QueryId=22021*

5.1.3 Domestic ownership of inventions made abroad under the USPTO

The domestic ownership of inventions made abroad under the USPTO in the OECD countries increased by 18.6%, from 270,147 patents in 2000 to 320,455 patents in 2013. Starting in 2000 when the patents accounted for 270,147, the highest peak was noticed after six years that they have risen by 27.9%, whereas the drop (-10.7%) during the following three years resulted in 308,582 patents in 2009. Looking more closely to Germany, the domestic ownership of inventions made abroad under the USPTO have increased by 6.1% from 13,883 patents in 2000 to 14,728 patents in 2013. Within seven years (2000-2007) the number of patents showed the most remarkable increase (63.8%), ranging from 13,883 patents in 2000 to 22,735 patents in 2007. The most significant decline in the patents was observed between 2010 and 2013 by a percentage of -33.8%, starting form 22,241 patents to 14,728 patents in 2013.

In the UK, the domestic ownership of inventions made abroad under the USPTO have grown by 13.6%, from 4,061 patents in 2000 to 4,612 patents in 2013. The sharpest increase was calculated in a percentage of 113.9% between 2000 and 2006, being 4,061 and 8,688 patents respectively, whereas the most significant reduction (-47.0%) was observed between 2009 and 2013, from 8,684 patents in 2009 to 4,612 patents in 2013.

The domestic ownership of inventions made abroad under the USPTO in the US increased by 28.9% from 131,638 patents in 2000 to 169,714 patents in 2013. While in 2003 the patents counted for 138,033, a rise by 26.9% gave them a value of 175,169 patents in 2007, whereas between 2012 and 2013 they showed a decrease by -4.5%, starting form 177,670 patents in 2012 to 169,714 patents in 2013 (Table 7).

Table 7. Domestic ownership of inventions made abroad, USPTO (2000 – 2013)

	DEU	GRC	UK	USA	OECD
2000	13,883	28	4,061	131,638	270,147
2001	14,063	21	4,127	134,278	294,415
2002	15,995	58	5,034	141,053	306,975
2003	17,319	73	6,134	138,033	315,422
2004	20,721	78	7,045	155,648	331,724
2005	21,566	124	7,744	166,810	334,024
2006	22,131	110	8,688	172,183	345,476
2007	22,735	145	8,627	175,169	344,685
2008	22,027	133	8,833	169,730	327,041
2009	21,629	138	8,684	154,764	308,582
2010	22,241	109	8,697	159,423	322,906
2011	21,224	111	8,516	166,137	331,138
2012	19,353	116	6,679	177,670	346,980
2013	14,728	75	4,612	169,714	320,455
Δ	***6.1%***	***167.9%***	***13.6%***	***28.9%***	***18.6%***

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

In Greece, a surprising increase (167.9%) was perceived in the number of domestic ownership of inventions made abroad under the USPTO, counting for 28 patents in 2000 to 75 patents in 2013. However, fluctuations occurred during this period of time. A decrease by -25.0% caused a decrease from 28 patents in 2000 to 21 patents in 2001, followed by a sharp increase (490.5%) within the next five years, resulting in 124 patents in 2005; then, a drop by -11.3% lead to 110 patents in 2006; despite the rise by 31.8% which led to 145 patents in 2007, the decline during the following year by -8.3% resulted in 133 patents in 2008, which was almost balanced though by the increase noticed in 2009 (3.8%) when the patents counted for 138. Finally, a significant decrease (-45.7%) resulted in 75 patents in 2013 instead of 138 patents in 2009 (Figure 13).

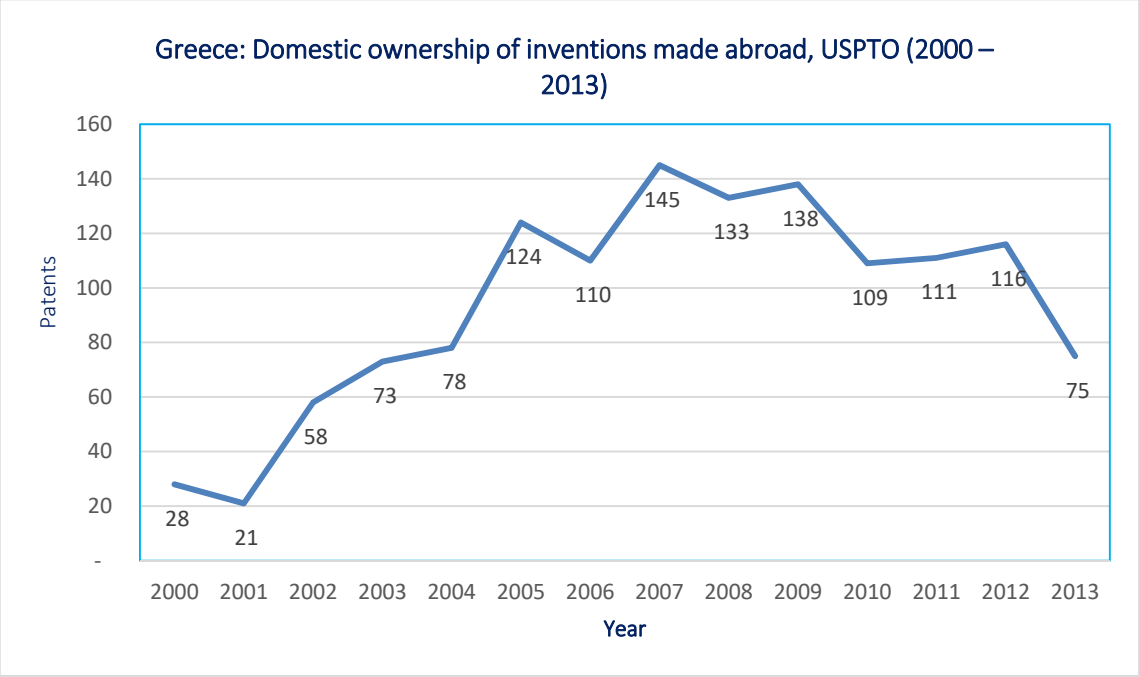


Figure 13. Greece: Domestic ownership of inventions made abroad, USPTO (2000 – 2013)

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

5.1.4 Domestic ownership of inventions made abroad under the EPO

The domestic ownership of inventions made abroad under the EPO in the OECD countries has increased by 23.2%, from 114,523 patents in 2000 to 141,376 patents in 2013. Although a significant decrease (-31.4%) in the number of patents was noted between 2010 and 2011, being 123,106 and 84,480 patents respectively, their number raised to 138,153 in 2012, expressing a growth by 63.5%. In Germany, the domestic ownership of inventions made abroad under the EPO increased by 0.3% from 21,981 patents in 2000 to 22,040 patents in 2013. The most remarkable rise, being 12.9%, was observed between 2002 and 2007, where the patents climbed from 21,532 to 24,312, whereas the most noticeable drop, being -8.1%, was noticed between 2010 and 2013, from 23,976 to 22,040 patents respectively. Looking at the same data derived from the UK, an overall decline by -7.8% from 5,152 patents in 2000 to 4,748 patents in 2013 was reported. Despite the increase (7.8%) calculated during 2012 and 2013 from 4,368 to 4,748 patents, a reduction by -11.4% dominated within the initial five years of the studied period, from 5,152 to 4,564 patents. On the other hand, an increase (14.6%) in the domestic ownership of inventions made abroad under the EPO was noted in the US,

accounting for 33,967 patents in 2000 and 38,920 patents in 2013. An upward trend has been perceived between 2002 and 2005, where the amount of patents ranged from 34,195 to 38,584. However, during the following five years, a decrease by -19.0% resulted in the patents being 31,246 in 2010 as opposed to 38,584 patents in 2005 (Table 8).

Table 8. Domestic ownership of inventions made abroad, EPO (2000 – 2013)

	DEU	GRC	UK	USA	OECD
2000	21,981	51	5,152	33,967	114,523
2001	21,727	62	4,840	33,151	112,442
2002	21,532	57	4,641	34,195	115,376
2003	21,809	70	4,664	35,387	120,522
2004	22,804	52	4,564	37,201	127,547
2005	23,841	90	4,718	38,584	131,227
2006	24,265	88	4,856	36,235	129,604
2007	24,312	99	4,835	33,793	126,111
2008	23,267	81	4,601	32,405	120,267
2009	23,784	86	4,527	31,344	120,606
2010	23,976	61	4,383	31,246	123,106
2011	23,738	70	4,404	33,851	84,480
2012	22,714	81	4,368	35,197	138,153
2013	22,040	80	4,748	38,920	141,076
Δ	***0.3%***	***56.9%***	***-7.8%***	***14.6%***	***23.2%***

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

In Greece, the number of domestic ownership of inventions made abroad under the EPO surged by 56.9%, from 51 patents in 2000 to 81 patents in 2013. However, data varied within this period, expressing a similar pattern though. Although the lowest peak was noted in 2000 when the patents counted for 51, an increase by 21.6% within the next year resulted in 62 patents in 2001, followed by a reduction (-8.1%) to 57 patents in 2002; a raise by 22.8% led to 70 patents in 2003, which have been declined afterwards (-25.7%) to 52 in 2004; while a sharp increase by 73.1% between 2004 and 2005 gave rise to the patents accounting for 90 in 2005, the decrease by -18.2% between 2007 and 2008 cause the number of patents to fall from 99 to 81 respectively; an increase by 6.2% to 86 patents in 2009 was followed by a significant decrease (-29.1%) which resulted in 61 patents in 2010 and finally, a sharp increase by 32.8% between 2010 and 2012, from 61 patents in 2010 to 81 patents in 2012 was observed (Figure 14).

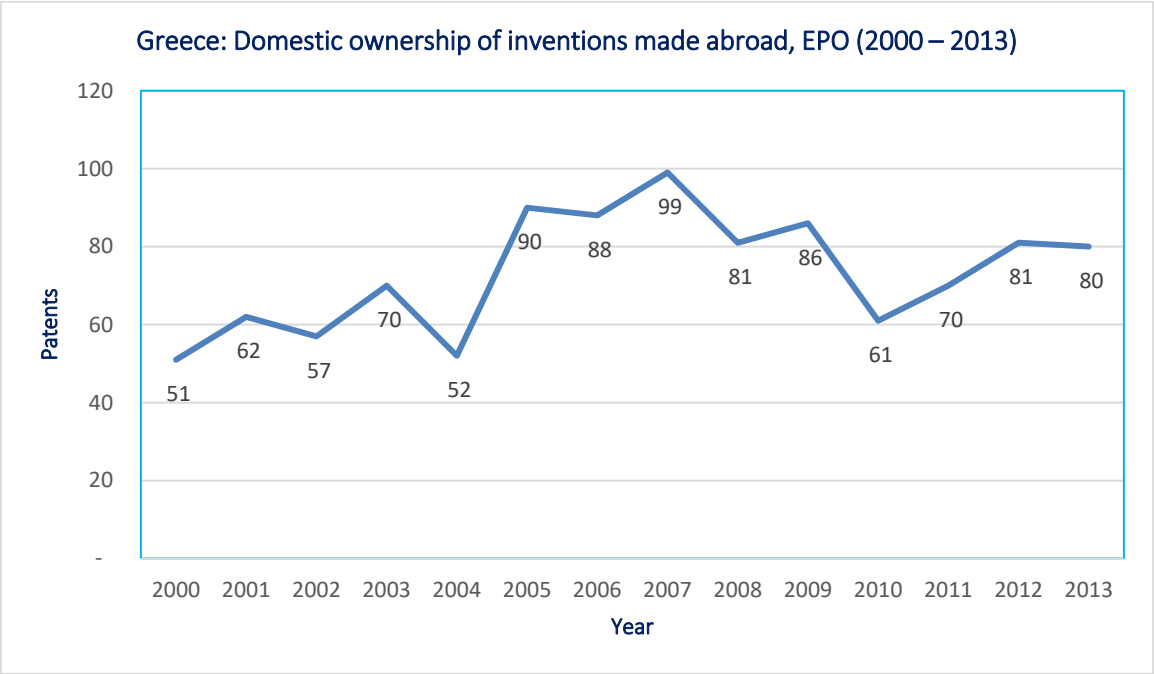


Figure 14. Greece: Domestic ownership of inventions made abroad, EPO (2000 – 2013)

Source: http://stats.oecd.org/Index.aspx?QueryId=22021

5.2 Grants by private agencies and NGOs

Grants by private voluntary agencies and non-government organizations (NGOs) are funds offered by private agencies and NGOS to support innovation and competitiveness. The funding is usually in cash, but it can also take the form of goods and/or services. Funding from the private sector is crucial, especially in the open economies that allow and facilitate the transfer of knowledge and technology between different countries or industries.

In Germany, grants showed a slight decrease (-0.4%), from $1,232.7 million in 2000 to $1,228.0 million in 2013. The sharpest increase by 36.2% has been noted between 2002 and 2005, from $1,143.4 million in 2002 to $1,557.7 million in 2005, whereas the sharpest decrease by -25.7% was observed between 2005 and 2007, from $1,557.7 million in 2005 to $1,157.1 million in 2007. On the other hand, in the UK, the grants have significantly surged by 39.9%, being $724.3 million in 2000 and $1,013.6 million in 2013. The sharpest increase was calculated in 192.2% between 2009 and 2012, climbing

from $351.9 million in 2009 to 1,028.4 million in 2012, whereas the sharpest decrease (-52.2%) was noticed between 2005 and 2009, from $735.5 million in 2005 to $351.9 million in 2009. A surprising upsurge by 386.9% has been achieved in the US, earning $26,613.4 million in 2013 compared to 5,465.8 million in 2000. The sharpest increase by 247.2 % was reported between 2000 and 2008, from 5,465.8 million to $18,977.0 million respectively, whereas the decline by -6.4% in 2013, caused a decrease from 28,434.7 million in 2012 to $26,613.4 million in 2013 (Table 9).

Table 9. Grants by government agencies and NGOs (2000-2013)

In $ m	DEU	GRC	UK	USA
2000	1,232.7		724.3	5,465.8
2001	1,197.2		459.9	6,000.7
2002	1,143.4	7.8	466.2	7,398.8
2003	1,153.8	8.5	461.3	8,022.7
2004	1,182.0	17.1	402.6	8,383.2
2005	1,557.7	0.5	735.5	10,318.0
2006	1,360.4	9.0	527.6	10,484.3
2007	1,157.1	5.6	582.0	13,742.9
2008	1,392.7	1.4	433.6	18,977.0
2009	1,193.9	1.5	351.9	17,916.6
2010	1,332.2	8.3	374.8	28,143.6
2011	1,370.2	0.1	634.9	27,823.5
2012	1,278.3	0.6	1,028.4	28,434.7
2013	1,228.0		1,013.6	26,613.4
Δ	***-0.4%***	***-92.9%***	***39.9%***	***386.9%***

Source: https://data.oecd.org/drf/grants-by-private-agencies-and-ngos.htm

In Greece, grants have significantly decreased by 92.9%, from $7.8 million in 2002 to $0.6 million in 2012, with extreme fluctuations in between. Despite the grants being increased by 119.6% from $7.8 million in 2002 to $17.1 million in 2004, a remarkable decline by -97.1% in 2005 caused the grants to account for only $0.5 million in 2005; although a rise resulted in $9.0 million in 2006, it was followed by a sharp reduction (-83.5%), from $9.0 million in 2006 to $1.5 million in 2009; then, the grants raised by 456.0% to $8.3 million in 2010, but declined by -98.4% to $0.1 million next year. Finally, in 2012, grants increased by 310.2% to reach at $0.6 million in 2012 (Figure 15).

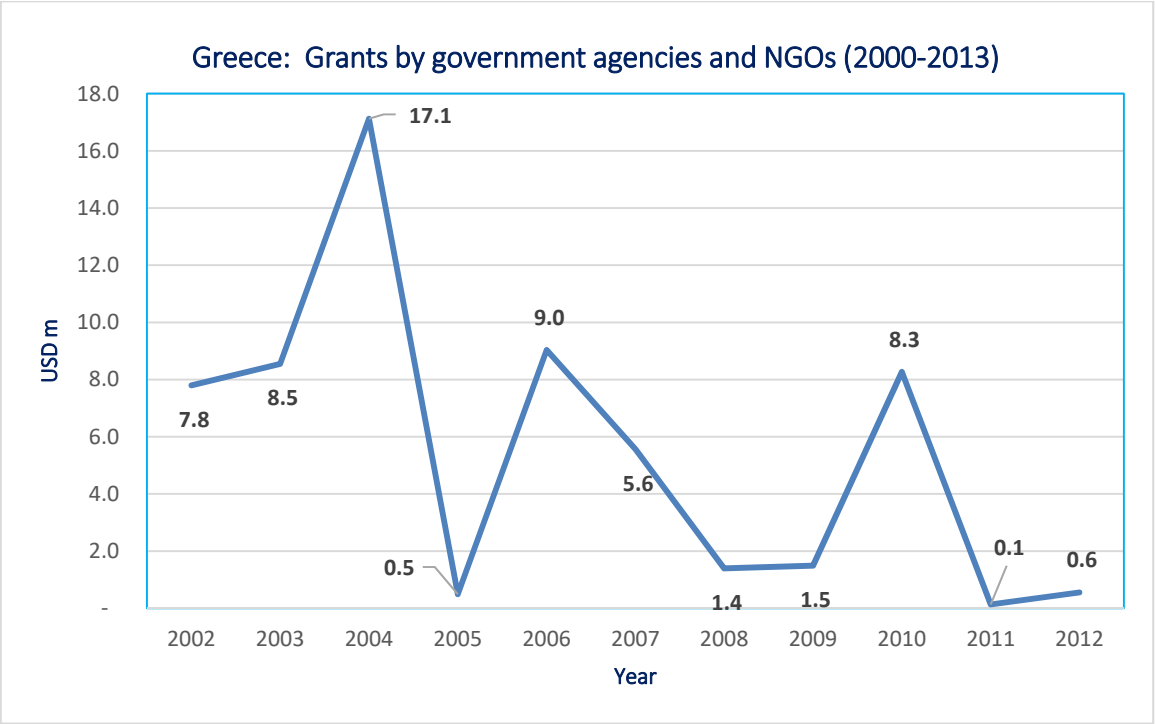


Figure 15. Grants by government agencies and NGOs (2000-2013)

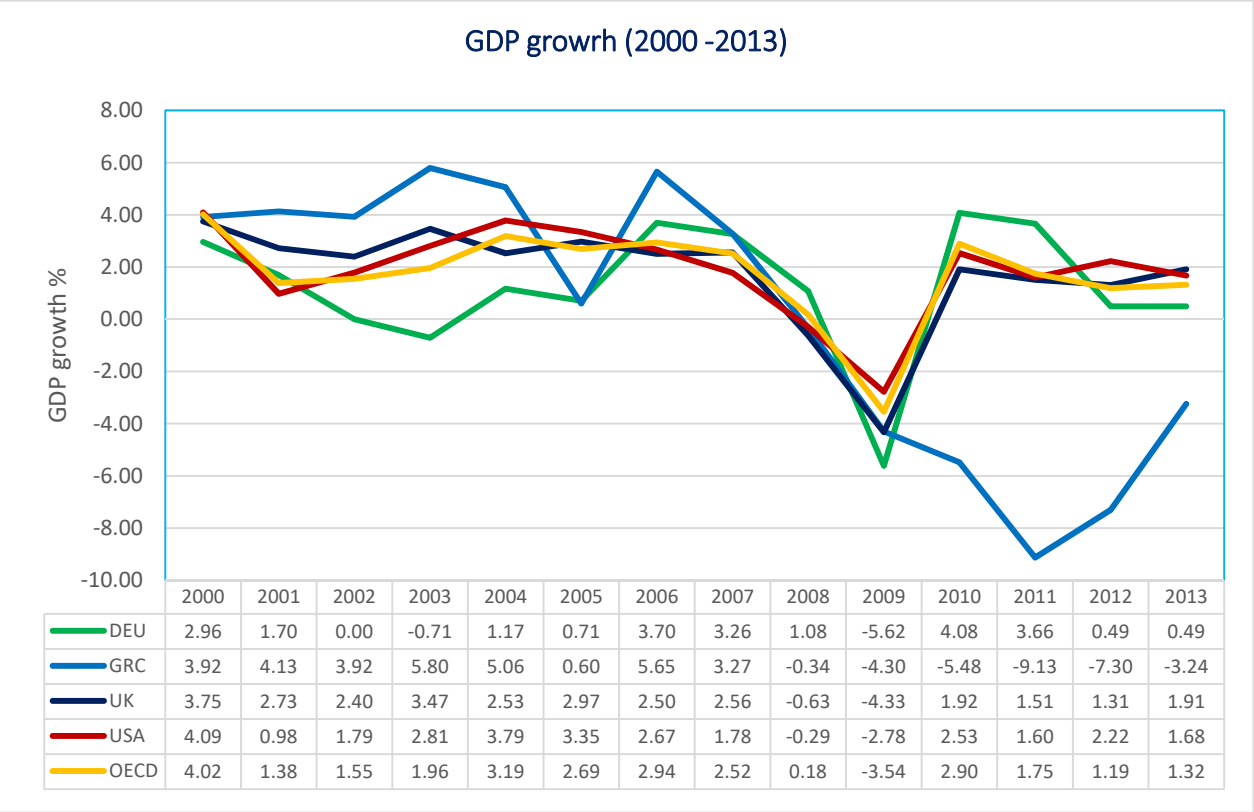
Source: https://data.oecd.org/drf/grants-by-private-agencies-and-ngos.htm

5.3 GDP Growth

Gross domestic product (GDP) represents the net expenditure on final goods and services, which embodies the final consumption expenditures, the gross capital formation and the net trade balance (exports – imports). Domestic defines the product which is produced with the use of the production factors in the resident country, while gross indicates that the use of machinery and capital assets use in the production are not depreciated (OECD, 2017).

The average GDP growth for the OECD countries was 171.7% for the period 2000 – 2013, with a decrease in 2009 by -3.54% and the highest value, being 4.02, in 2002. In Germany, the average GDP growth for the period 2000 – 2013 was calculated at 121.2%, with a decline in 2009 by -5.62% and the highest value, 4.08, in 2010. In the UK, the average GDP growth for the period 2000 – 2013 was calculated at 175.6%, with a drop by -4.33 in 2009 and the highest peak in 2003. In the US, the average GDP growth between 2000 and 2013 was 187.2%, with a reduction by -2.78 in 2009 and the highest

value, 4.09, in 2000. Greece reached the sharpest peak in 2011, -9.13, expressing the worst GDP performance from 2009 onwards. Thus, the average GDP growth for the period 2000 – 2013 was calculated at 18.3%, with the highest value 5.80% in 2003 (Figure 16).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
DEU	2.96	1.70	0.00	-0.71	1.17	0.71	3.70	3.26	1.08	-5.62	4.08	3.66	0.49	0.49
GRC	3.92	4.13	3.92	5.80	5.06	0.60	5.65	3.27	-0.34	-4.30	-5.48	-9.13	-7.30	-3.24
UK	3.75	2.73	2.40	3.47	2.53	2.97	2.50	2.56	-0.63	-4.33	1.92	1.51	1.31	1.91
USA	4.09	0.98	1.79	2.81	3.79	3.35	2.67	1.78	-0.29	-2.78	2.53	1.60	2.22	1.68
OECD	4.02	1.38	1.55	1.96	3.19	2.69	2.94	2.52	0.18	-3.54	2.90	1.75	1.19	1.32

Figure 16. GDP growth (2000-2013)

Source: http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2013&locations=DE-GR-GB-US-OE&start=2000&view=chart

5.4 Employment rate

Employment rates measures the extent to which available labour resources, i.e. people available to work, are being used. The employment rate is calculated reliant upon employed people over the working age population. Analysts consider the long-term employment (and unemployment rates) to make their future estimates, because short-employment is subject to cyclicality and may not generate accurate results. Also, the working age population involves people aged between 15 and 64 years old (OECD, 2017g).

The average employment rate for the four countries for the period 2000-2013 was calculated at 70.3% in Germany, 57.5% in Greece, 70.9% in the UK, 70.0% in the United States and 65.3% in the OECD countries (Figure 17).

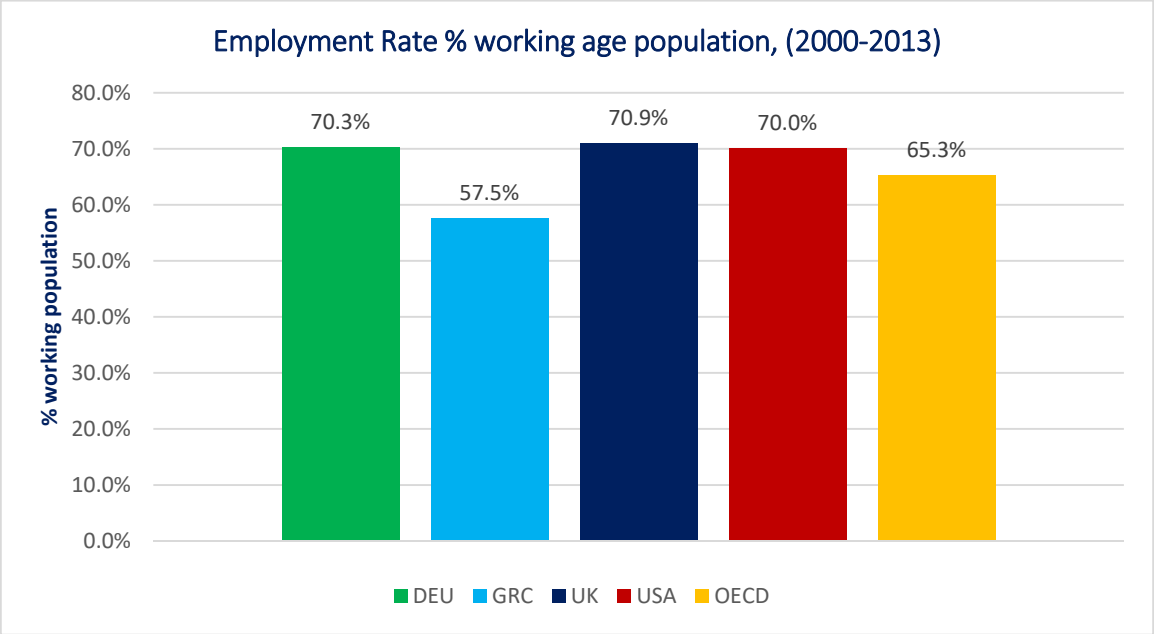


Figure 17. Employment Rate % working age population, (2000-2013)

Source: https://data.oecd.org/emp/employment-rate.htm

5.5 Comparative analysis

This section performs a comparative analysis between Germany, Greece, the UK and the United States in order to identify where Greece stands compared to the other countries in terms of innovation and R&D.

Patent growth for foreign ownership of domestic inventions (FODI) under the USPTO for the period 2000 - 2013 was 114.3% for Greece and 16.1% for the United States, while it was -16.4% for Germany and -16.3% for the UK. Patent growth for foreign ownership of domestic inventions (FODI) under the EPO for the same period was 71.6% for Greece and 18.2% for the United States, while it was -0.9% for Germany and -3.4% for the UK.

Patent growth for domestic ownership of inventions made abroad (DOMA) under the USPTO for the period 2000 – 2013 was positive for all four counties, being 6.1% for

Germany, 167.9% for Greece, 13.6% for the UK and 28.9% for the United States. Patent growth for domestic ownership of inventions made abroad (DOMA) under the EPO for the period 2000 – 2013 was positive for Germany 0.3%, Greece 56.9% and the United States 14.6%, but negative -7.8% for the UK.

Grants growth for the period 2000 – 2013 was -0.4% for Germany and -92.9% for Greece, while it was 39.9% for the UK and 386.9% for the United States. Researchers' growth for the period 2000 – 2013 was 29.6% for Germany, 106.9% for Greece, 43.6% for the UK and 26.4% for the United States. The average GDP growth for the period 2000 – 2013 was calculated to 121.2$ for Germany, 18.3% for Greece, 175.6% for the UK and 187.2% for the United States. The average gross domestic expenditure as a percentage of GDP for the same period accounts for 256.5% in Germany, 61.8% in Greece, 163.1% in the UK and 264.8% in the United States. Finally, the average employment rate for these thirteen years was 57.5% for Greece, 70.9% for the UK and 70.0% for the United States, while for Germany the average employment rate was calculated to 70.3% for the period 2005-2013 (Table 10).

Table 10. Comparative analysis (2000-2013)

USPTO	DEU	GRC	UK	USA
Patent growth FODI	-16.4%	114.3%	-16.3%	16.1%
Patent growth DOMA	6.1%	167.9%	13.6%	28.9%
Grants growth	-0.4%	-92.9%	39.9%	386.9%
Researchers growth	29.6%	106.9%	43.6%	26.4%
GDP growth	121.2%	18.3%	175.6%	187.2%
GERD % GPD	256.5%	61.8%	163.1%	264.8%
Employment rate	70.3%	57.5%	70.9%	70.0%

EPO	DEU	GRC	UK	USA
Patent growth FODI	-0.9%	71.6%	-3.4%	18.2%
Patent growth DOMA	0.3%	56.9%	-7.8%	14.6%
Grants growth	-0.4%	-92.9%	39.9%	386.9%
Researchers growth	29.6%	106.9%	43.6%	26.4%
GDP growth	121.2%	18.3%	175.6%	187.2%
GERD % GPD	256.5%	61.8%	163.1%	264.8%
Employment rate	70.3%	57.5%	70.9%	70.0%

Source: OECD statistics and own work

It is obvious from data presented in Table 5-6 that Greece exerts the lowest GDP growth 18.3%, the lowest gross domestic expenditure on R&D 61.8% and the lowest employment rate 57.5%. On the other hand, Greece is a leader in the patent growth for foreign ownership of domestic inventions (FODI) under the USPTO 114.3% and EPO

71.6%, in the patent growth for domestic ownership of inventions made abroad (DOMA) under the USPTO 167.9% and EPO 59.9% as well as in researchers' growth 106.9%. Although grants by the private sector and the NGOs has significantly decreased by -92.9%, Greek firms are increasingly investing in R&D human resources and innovative activity.

Chapter 6
Conclusion

One of the key characteristics of patents is that they trigger economic and technological development for the firms. Firms that engage in R&D are becoming increasingly competitive and acquire a financial motivation for invention that could contribute to public good. However, patent protection may inhibit R&D and economic growth. Inventive activities are broadly classified at the international level to foreign ownership of domestic inventions and to domestic ownership of inventions made abroad. In this context, inventions may be funded by foreign companies, sponsors in the residing country, non-governmental organizations (NGOs) and researchers from different countries, thereby enhancing cross-industry or cross-border innovation.

Based on the theoretical framework of the study, it is evident that there is a causal relationship between innovation, R&D and economic activity. Innovative firms are willing to invest in technology transfer and exchange of knowledge between countries or industries, aiming to capitalise on the growth potential of innovation and R&D. Although there are differences between the developed and the developing economies, with the latter being less likely to increase their innovation output by investing in R&D, the role of technological innovation as the key force for economic growth is well established.

Although patent protection was not practiced traditionally by firms, it seems that more and more countries are willing to protect their intellectual property rights nowadays. Patent growth under the United States Patent and Trademark Office (USPTO) for foreign ownership of domestic inventions in the period 2000 – 2013 was 114.3% for Greece and 16.1% for the United States. On the other hand, patent growth for Germany and the UK was negative, -16.4% and -16.3% respectively in the same category. Patent growth for domestic ownership of inventions made abroad under the USPTO was positive for all sample countries, suggesting that many firms prefer a foreign co-inventor in their patent. Furthermore, this fact highlights that they are becoming increasingly more open to the cross-border transfer of knowledge between firms. The results of patent growth for foreign ownership of domestic inventions under the USPTO in the period 2000 –

2013 were 71.6% for Greece and 18.2% for the United States, whereas both Germany and the UK had negative growth by -0.9% and -3.4% respectively. In patent growth for domestic ownership of inventions made abroad under the EPO, only the UK exerted negative growth by -7.8%.

Although strengthening patent protection may restrict economic growth as it increases the profit flow of innovation, it declines the factor demand for capital. Consequently, firms may not be able to accumulate a lot of capital when engaging heavily in R&D. On the other hand though, evidence derived from various firms on a global scale suggests that the protection of intellectual property rights and patent enhances the incentive to innovate, despite the higher complexity of the projects. Especially in the developed economies, IPR and patent protection contribute to innovation and economic growth. In the developing economies, a key factor is that firms that do not possess the technological knowledge to innovate are more likely to engage in R&D and protect their IPRs.

Firm structure also affects innovation. Firms that are open to the exchange of knowledge can integrate an ecosystem of diverse participants, who all collaborate publicly. Sharing knowledge, open participation and focus on the community are the most important factors in an open business model, along with the dimension of business innovation that pertain the firm's offerings (platform and solutions), customers (customer experience and value capture), processes (organization and supply chain) and overall market presence (networking and brand).

On the other hand, studies have identified a negative correlation between licensing and innovation, as firms which engage in licensing are more likely to experience fragmented intellectual property rights. Also, smaller firms with fewer production facilities and marketing channels tend to license more, whereas larger firms prefer to cross-license so that they can bring the product in the market with all the benefits incurred from exchanging licenses with another party. Moreover, licensing is found to be correlated to firm size, as larger firms tend to license less than smaller firms.

Greece has been mostly affected by the financial crisis that is still present on the country, affecting the business operations. However, the results of empirical analysis have demonstrated that although Greece has the lowest GDP growth by 18.3%, the lowest gross domestic expenditure on R&D by 61.8% and the lowest employment rate by 57.5%, it remains a leader in patent growth. More specifically, Greece incurred a 114.3%

patent growth for foreign ownership of domestic inventions (FODI) under the USPTO, and 71.6% patent growth under the EPO; 167.9% patent growth for domestic ownership of inventions made abroad (DOMA) under the USPTO and 59.9% patent growth under the EPO. Also, the country was the leader in researchers' growth 106.9% between 2000 and 2013. The results show that, although grants by the private sector and the NGOs have significantly decreased by -92.9%, Greek firms are increasingly investing in R&D human resources and innovative activity. In fact, the Greek financial crisis has created a new business environment of high uncertainty, but also of great opportunities for firms to offer "value for money".

Conclusively, the study suggests that firms which effectively employ the innovation mechanisms to attain new knowledge are more likely to successfully engage in R&D and benefit from innovation. Although, the ongoing financial crisis has affected the grants growth by the private sectors both under the USPTO and the EPO, the number of researchers and the gross domestic expenditure on R&D had a remarkable growth. The relation between the economic crisis and patent growth should be taken into consideration as, in the long-term, economic crises may reduce patenting activity.

6.1 Limitations of the study

Innovation and R&D remains one of the most delicate challenges. Most importantly, to measure the internationalisation of technology with patent information requires plentiful information on firm specific characteristics such as size, structure and strategy. This information was hard to be obtained for the scope of this study, especially because there is no public information available for all firms operating in the countries of interest. To address this problem, the study could obtain this information by performing qualitative analysis with survey-based data and/or questionnaires in particular firms in each country. Another limitation is that there are no statistical data available for 2014 and 2015. Therefore, the study is based on the latest statistical data of 2013 for the OECD database.

6.2 Guidelines for future research

Given the rapid technological innovation and the social and economic challenges, it would be interesting to investigate the evolution of patenting in selected West and East European countries and see how Greece compares. Also, considering that the economic crisis may be an impeding factor for innovation, it would be thought-provoking to evaluate the impact of financial crisis on innovation and R&D. Finally, as previously communicated, the results of the study would be more firm-oriented if it were feasible to perform a survey-based and/or questionnaire survey for specific firms in selected countries or in Greece.

References

Allred, B.B. and Park, W.G. (2007). Patent Rights and Innovative Activity: Evidence from National and Firm-Level Data, *Journal of International Business Studies*, vol. 38, No. 6, 878-900.

Anand, B.N. and Khanna, T. (2000), The Structure of Licensing Contracts, *Journal of Industrial Economics*, vol. 48, No 1, pp. 103-135.

Annique Un, C., Cuervo-Cazurra, A. and Asakawa, K. (2010). R&D Collaborations and Product Innovation. *Journal of Product Innovation Management*, Volume 27, Issue 5, pp. 673–689.

Antonietti, R., Bronzini, R. and Cainelli, G. (2015). Inward greenfield FDI and innovation. *Economia e Politica Industriale*, Vol. 42, Issue 1, pp. 93-116. (https://rd.springer.com/article/10.1007/s40812-014-0007-9 Abstract)

Archibugi, D., Filippetti, A. and Frenz, M. (2013). Economic crisis and innovation: Is destruction prevailing over accumulation? *Research Policy*, Volume 42, Issue 2, pp. 303–314.

Arora, A., Ceccagnoli, M. and Cohen, W.M. (2008). *R&D and the patent premium*. [online] ScienceDirect http://www.sciencedirect.com/science/article/pii/S0167718707001373 [accessed 20 Mar. 2017].

Artz, K.W., Norman, P.M., Hatfield, D.E. and Cardinal, L.B. (2010). A Longitudinal Study of the Impact of R&D, Patents, and Product Innovation on Firm Performance. *Journal of Product Innovation Management*, Volume 27, Issue 5, pp. 725–740.

Bessen, J. and Meurer, M.J. (2006). Patent Litigation with Endogenous Disputes. *American Economic Review*, Vol. 96, No. 2, pp. 77-81.

Boermans, M.A and Roelfsema, H. (2013). The effects of managerial capabilities on export, FDI and innovation: Evidence from Indian firms. *Asian Business & Management*, Volume 12, Issue 4, pp 387–408. (https://rd.springer.com/article/10.1057%2Fabm.2013.7 Abstract)

Boldrin, M. and Levine, D. K. (2013). The Case Against Patents. *The Journal of Economic Perspectives*, Volume 27, Number 1, pp. 3-22.

Braunerhjelm, P. (2012). Entrepreneurship, Innovation and Economic Growth Past experiences, current knowledge and policy implications. *Swedish Entrepreneurship Forum*, Working Paper 2010:02.

Chesbrough, H.W. (2007). *Why Companies Should Have Open Business Models*. [online] MIT Sloan Management Review. Available at: http://sloanreview.mit.edu/article/why-companies-should-have-open-business-models/ [accessed 20 Mar. 2017].

Chesbrough, H.W., West, J. and Vanhaverbeke, W. (2006) *Open Innovation: Researching a New Paradigm*. Oxford: Oxford University Press.

Clancy, M.S. and Moschini, G. (2013). Incentives for Innovation: Patents, Prizes, and Research Contracts. *Applied Economic Perspectives and Policy*, volume 35, number 2, pp. 206–241.

Coad, A. and Rao, R. (2010). Firm growth and R&D expenditure. *Economics of Innovation and New Technology*, Volume 19, Issue 2, pp. 127-145.

Cockburn, I.M., MacGarvie, M.J and Müller, E. (2010). Patent thickets, licensing and innovative performance. *Industrial Corporate Change*, Volume 19, Issue 3, pp. 899-925.

Cozza, C, and Zanfei, A. (2014). The cross-border R&D activity of Italian business firms. *Economia e Politica Industriale*, Vol. 41, Issue 3, pp.39-64.

Dasher, R.B. (2009*) Technology Strategies in Silicon Valley and Asia: Contrasting Patterns of Open Innovation*. [online] Stanford University. Available at: http://web.stanford.edu/group/us-atmc/cgi-bin/us-atmc/wp-content/uploads/2009/09/090924-dasher402a-part2.pdf [accessed 5 Mar. 2017].

Demirel, P. and Mazzucato, M. (2012). Innovation and Firm Growth: Is R&D Worth It? *Journal of Industry and Innovation*, Volume 19, Issue 1, pp. 45-62.

De Marchi, V. (2012). Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms. *Research Policy*, Volume 41, Issue 3, pp.614–623.

Djankov, S., Ganser, T., McLiesh, C., Ramalho, R. and Shleifer, A. (2009). *The Effect of Corporate Taxes on Investment and Entrepreneurship.* [online] Available at: https://dash.harvard.edu/bitstream/handle/1/8705900/AEJMacro.pdf?sequence=1 [accessed 5 Mar. 2017].

Enkel, E. and Gassmann, O. (2010). Creative imitation: exploring the case of cross-industry innovation. *Journal of R&D Management*, Volume 40, Issue 3, pp 256–270.

EPO (2017). *Mission and vision*. [online] EPO. Available at: https://www.epo.org/about-us/office/mission.html [accessed 22 Apr. 2017].

European Union (2009). *Better careers and more mobility*: a European partnership for researchers. [online] European Union. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008AE1908&from=EN [accessed 20 Apr. 2017].

Falk, M. (2009). *Quantile estimates of the impact of R&D intensity on firm performance*. [online] Austrian Institute of Economic Research. Available at:http://martin.falk.wifo.ac.at/fileadmin/homepage_falk/files/RD_growth_2009_final.pdf [accessed 20 Mar. 2017].

Fu, X., Pietrobelli, C. and Soete, L. (2011). The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-up. *World Developmen*t, Volume 39, Issue 7, pp. 1204–1212.

Galindo, M.A. and Méndez, M.T. (2014). Entrepreneurship, economic growth, and innovation: Are feedback effects at work? *Journal of Business Research*, Volume 67, Issue 5, pp. 825–829.

Gambardella, A., Giuri, P. and Luzzi, A. (2007). The market for patents in Europe. *Research Policy*, Volume 36, Issue 8, pp. 1163–1183.

Gassmann, O., Daiber, M. and Enkel, E. (2011). The role of intermediaries in cross-industry innovation processes. *Journal of R&D Management*, Volume 41, Issue 5, pp. 457–469.

Gassmann, O., Enkel, E. and Chesbrough, H. (2010). The future of open innovation. *Journal of R&D and Management*, Volume 40, Issue 3, pp. 213–221.

Global Innovation Index (2016). Available at: https://www.globalinnovationindex.org/analysis-indicator [accessed 4 Mar. 2017].

Grabowski, H.G., DiMasi, J. A. and Long, G. (2015). The Roles Of Patents And Research And Development Incentives In Biopharmaceutical Innovation. *Health Affairs*, Vol. 34, No. 2, pp.302-310.

Granstrand, O. (2011). *Patents and Innovation for Growth in a Converging World Economy.* Intellectual Property Strategy and Technology Commercialization. Presentation at the World Intellectual Property Organisation WIPO. [online] Available at: http://www.wipo.int/edocs/mdocs/mdocs/en/wipo_ip_econ_ge_4_11/wipo_ip_econ_ge_4_11_www_182037.pdf [accessed 5 Mar. 2017].

Hall, B.H. (2013). *Innovation, patents, and productivity in firms*. [online] Berkeley University. Available at: https://eml.berkeley.edu/~bhhall/papers/BHH13_Industry_Canada_innov_patents_prod.pdf [accessed 1 Mar. 2017].

Hall, B.H., Grid, T. and Torrisi, S. (2007). *The market value of patents and R&D, Evidence from European Firms.* NBER Working Paper, [online] Rady School of Management. Available at: http://rady.ucsd.edu/faculty/seminars/2010/papers/hall.pdf [accessed 20 Feb. 2017].

Hall, B.H., Lotti, F. and Mairesse, J. (2013). Evidence on the impact of R&D and ICT investments on innovation and productivity in Italian firms. *Economics of Innovation and New Technology*, Volume 22, Issue 3, pp. 300-328

Hashi, I. and Stojcic, N. (2010). The Impact of innovation activities on firm performance using a multi-stage model: evidence from the Community Innovation Survey 4. *Research Policy*, Volume 42, Issue 2, pp. 353–366.

Hausman, A. and Johnston, W.J. (2014). The role of innovation in driving the economy: Lessons from the global financial crisis. *Journal of Business Research*, Volume 67, Issue 1, pp. 2720–2726.

Heller, M.A. and Eisenberg, R.S. (1998). Can Patents Deter Innovation? *The Anticommons in Biomedical Research*. Science, Vol. 280, pp. 698-701.

Hemel, D.J. and Larrimore Ouellette, L. (2013). Beyond the Patents-Prizes Debate. Texas Law Review, Vol. 92, No. 2, pp. 303 -382.

Holgersson, M. (2013). Patent management in entrepreneurial SMEs: a literature review and an empirical study of innovation appropriation, patent propensity, and motives. *Journal of R&D and Management*, Volume 43, Issue 1, pp. 21–36.

Iwaisako, T. and Futagami, K. (2013). Patent protection, capital accumulation, and economic growth. *Economic Theory*, Volume 52, Issue 2, pp 631–668.

Kim, Y.K., Lee, K., Park, W.G. and Choo, K. (2012). Appropriate intellectual property protection and economic growth in countries at different levels of development. *Research Policy*, Volume 41, Issue 2, pp. 358–375.

Komninos, N. and Tsamis, A. (2008). The system of innovation in Greece: structural asymmetries and policy failure. *International Journal of Innovation and Regional Development*, Volume 1, Issue 1, pp.1-23.

Korres, G.M. and Drakopoulos, S. (2009). Economics of Innovation: A Review in Theory and Models. *European Research Studies*, Volume XII, Issue 3, pp.25-38.

Kostopoulos, K., Papalexandris, A., Papachroni, M and Ioannou, G (2011). Absorptive capacity, innovation, and financial performance. *Journal of Business Research*, Volume 64, Issue 12, pp.1335–1343.

Manolopoulos, D., Papanastassiou, M. and Pearce, (2007). Knowledge-related competitiveness and the roles of multinationals' R&D in a peripheral European economy: Survey analysis of Greece. *Management International Review*, Volume 47, Issue 5, pp 661–682. [online] Available at: http://www.freepatentsonline.com/article/Management-International-Review/171851362.html [accessed 6 Mar. 2017].

Maresch, D., Fink, M. and Harm, R. (2016). When patents matter: The impact of competition and patent age on the performance contribution of intellectual property rights protection. *Technovation*, Volumes 57–58, pp. 14–20.

Mehlig Sweet, C. and Eterovic-Maggio, D. S. (2015). Do Stronger Intellectual Property Rights Increase Innovation? *World Development*, Volume 66, pp. 665–677.

Moser, P and Nicholas, T. (2013). Prizes, Publicity and Patents: Non-Monetary Awards as a Mechanism to Encourage Innovation. *Journal of Industrial Economics*, Volume 61, Issue 3, pp. 763–788.

Motohashi, K. (2008). Licensing or not licensing? An empirical analysis of the strategic use of patents by Japanese firms. *Research Policy*, Volume 37, Issue 9, pp. 1548–1555.

Nicholas, T. (2011). Did R&D Firms Used to Patent? Evidence from the First Innovation Surveys. *Journal of Economic History*, Volume 71, Issue 4, pp. 1032-1059.

OECD (2009). *OECD Patent Statistics Manual*. [online] OECD. Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-patent-statistics-manual_9789264056442-en;jsessionid=w8ckczcdpgmr.x-oecd-live-03 [accessed 23 Apr. 2017].

OECD (2011). *Measuring Innovation: A New Perspective*. [online] OECD. Available at: http://www.oecd.org/site/innovationstrategy/45184357.pdf [accessed 6 Mar. 2017].

OECD (2012). *Innovation in the Crisis and Beyond.* [online] OECD. Available at: https://www.oecd.org/sti/sti-outlook-2012-chapter-1-innovation-in-the-crisis-and-beyond.pdf [accessed 20 Mar. 2017].

OECD (2016). *Entrepreneurship at a Glance 2016*. [online] OECD. Available at: http://www.oecd-ilibrary.org/industry-and-services/entrepreneurship-at-a-glance_22266941 [accessed 22 Apr. 2017].

OECD (2017*). Research and Development Statistics (RDS).* [online] OECD. Available at: http://www.oecd.org/innovation/inno/researchanddevelopmentstatisticsrds.htm [accessed 20 Mar. 2017].

OECD (2017a). *Gross domestic expenditure on R-D by sector of performance and socioeconomic objective.* [online] OECD. Available at:

https://stats.oecd.org/Index.aspx?DataSetCode=BERD_INDUSTRY# [accessed 20 Mar. 2017].

OECD (2017b) *Gross domestic spending on R&D*. [online] OECD. Available at: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm#indicator-chart [accessed 20 Apr. 2017].

OECD (2017c) *Government Researchers*. [online] OECD. Available at: https://data.oecd .org/rd/government-researchers.htm#indicator-chart [accessed 20 Apr. 2017].

OECD (2017d) *Triadic patent families*. [online] OECD. Available at: https://data.oecd.org/rd/triadic-patent-families.htm#indicator-chart [accessed 20 Apr. 2017].

OECD (2017e). *Foreign ownership of domestic inventions in patents granted by the USPTO & the EPO* [online] OECD. Available at: http://stats.oecd.org/Index.aspx?QueryId=22021 [accessed 22 Apr. 2017].

OECD (2017f). *Grants by government agencies and NGOS*. [online] OECD. Available at: https://data.oecd.org/drf/grants-by-private-agencies-and-ngos.htm [accessed 22 Apr. 2017].

OECD (2017g). *Employment Rate.* [online] OECD. Available at: https://data.oecd.org/emp/employment-rate.htm [accessed 22 Apr. 2017].

Owen, S. and Yawson, A. (2015). R&D intensity, cross-border strategic alliances, and valuation effects. *Journal of International Financial Markets, Institutions and Money*, Volume 35, pp. 1–17.

PwC (2015). *2015 Global Innovation 1000*. [online] Strategy&PwC. Available at: https://www.strategyand.pwc.com/media/file/2015-Global-Innovation-1000-Fact-Pack.pdf [accessed 20 Mar. 2017].

Qian, Y. (2007). *Do National Patent Laws Stimulate Domestic Innovation in a Global Patenting Environment? A Cross-Country Analysis of Pharmaceutical Patent Protection, 1978–2002.* [online] The Review of Economics & Statistics. Available at: http://users.nber.org/~yiqian/rest.89.3.pdf [accessed 22 Apr. 2017].

Regibeau, P. and Rockett, K. (2011) *Assessment of potential anticompetitive conduct in the field of intellectual property rights and assessment of the interplay between competition policy and IPR protection*. [online] EC. Available at: http://ec.europa.eu/competition/consultations/2012_technology_transfer/study_ipr_en.pdf [accessed 20 Feb. 2017].

Sawhney, M., Wolcott, R.C. and Arroniz, I. (2006). The 12 Different Ways for Companies to Innovate. *MIT Sloan Management Review*, pp. 28-34.

Shughart, W.F. and Thomas, D.W. (2015). Intellectual Property Rights, Public Choice, Networks, and the New Age of Informal IP Regimes. *Supreme Court Economic Review*, Vol. 23, No. 1.

Spulber, D.F. (2014). Prices versus Prizes: Patents, Public Policy, and the Market for Inventions. Northwestern Law & Econ Research Paper, No. 14-15.

Statista (2017). *Percentage of global research and development spending in 2016, by industry.* [online] Statista. Available at: https://www.statista.com/statistics/270233/percentage-of-global-rundd-spending-by-industry/ [accessed 20 Mar. 2017].

Stiebale, J. (2016). Cross-border M&As and innovative activity of acquiring and target firms. Journal of International Economics, Volume 99, pp. 1–15.

Stiebale, J. (2013). The impact of cross-border mergers and acquisitions on the acquirers' R&D — Firm-level evidence. *International Journal of Industrial Organization*, Volume 31, Issue 4, pp. 307–321.

Ulku, H. (2004). *R&D, Innovation, and Economic Growth: An Empirical Analysis.* IMF Working Paper [online] IMF. Available at: https://www.imf.org/external/pubs/ft/wp/2004/wp04185.pdf [accessed 20 Feb. 2017].

USPTO (2017). *General information concerning patents.* [online] USPTO. Available at: https://www.uspto.gov/patents-getting-started/general-information-concerning-patents#heading-1 [accessed 22 Apr. 2017].

US Legal (2017). *Cross-Licensing Agreement Law and Legal Definition. [online] US Legal.* Available at: https://definitions.uslegal.com/c/cross-licensing-agreement/ [accessed 24 Apr. 2017].

Vahter, P. (2010). Does FDI Spur Innovation, Productivity and Knowledge Sourcing by Incumbent Firms? Evidence from Manufacturing Industry in Estonia. *University of Nottingham.* Research Paper No. 2010/09.

Wang, J.H. (2007). *From technological catch-up to innovation-based economic growth: South Korea and Taiwan compared*. [online] National Chengchi University. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.483.2980&rep=rep1&type=pdf [accessed 24 Apr. 2017].

World Bank (2017). *GDP growth* (*annual %).* [online] World Bank. Available at: http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2013&locations=DE-GR-GB-US-OE&start=2000&view=chart [accessed 24 Apr. 2017].

Ying Y., Yang L. and Cong, C. (2016). R&D activities dispersion and innovation: implications for firms in China. *Asian Journal of Technology Innovation*, Volume 24, Issue 3, pp. 361-377.