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Basic R&D and the Business Cycle. An Exploratory Account for the EU Countries

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Bio

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Osvaldo works since 2007, having collaborated with several companies as a SAP Technology Consultant, where he developed technical and business skills related to SAP ERP (Enterprise Resource Planning), and, more recently, as project manager he is the responsible for the design, development, implementation, and support of SAP projects in large Portuguese companies like Unicer, Porto Editora, ONI, Sonae Capital and Sonae Sierra. In September 2014 he accepted a new challenge from NOS Sistemas and he is currently working as Client Coordinator and Technical Advisor.

He enjoys playing sports and he is currently working in some ideas related to this subject that could become startup projects. During the first semester of 2014 he formed a team to develop one of these ideas and was accepted in the 3rd Edition of Startup Acceleration Program at UPTEC in Porto. The project is on hold at the present time, but the participation in the UPTEC program was a huge help to consolidate the knowledge gathered in MIETE.

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Abstract

Over the last decades many European governments have pursued ambitious research and development (R&D) policies with the aim of fostering innovation and economic growth in the European Union. Most countries followed a pro-cyclical pattern, where the government budgets shrunk along slowing gross domestic product growth in similar pace with total government expenditure. For many countries, R&D can have two different paths, basic research or applied research, and the way governments promote one or another is likely to have a large impact on future economic performance of nations. Such debate is therefore critical for all countries, being important to assess how has the public investment in R&D evolved during the latest economic crisis, and whether there is any pattern or any major change in the distribution of R&D between basic and applied research over that period.

Thus, the present dissertation has two aims. First, to assess the trends on R&D expenditure both in the global and by type (basic vs applied). Second, to contribute to enhancing, at the level of EU's countries, the debate on the impact of the observed trends in basic R&D expenditures on countries' innovation and economic performance.

We adopted an exploratory, quantitative research methodology which allowed us to describe the patterns and evolution of countries' R&D intensity, basic R&D weight and the business cycle (GDP per capita growth).

Two main results were drawn from the analyses performed. First, in the transition between the periods before (2003-2008) and after (2009-2012) the economic and financial crisis, countries that present the highest innovation performance (leaders and followers) were associated with increased basic R&D ratios. In the moderate innovators group, characterized by lower levels of innovation performance, the basic R&D ratios evidenced a declining trend. Second, considering the overall averages for each period, we found evidence of a positive relation between basic R&D ratios variation and economic performance (i.e., real average GDP per capita economic growth).

Such outcomes suggest that the reduction in the weight of basic R&D observed in some countries that are going through fiscal consolidation strategies/programmes (supported by structural fiscal measures and control over public expenditures, aimed at putting the gross public debt-to-GDP ratio on a downward path), might endanger catching up processes by moderate innovators and thus contribute to widening their distance to the technological frontier.

Keywords: Basic research; Applied research; Research and development; Economic performance.

JEL-Codes: J82, L25, L50, O31, O38, O40

Index of Contents

Index of Tables

Index of Figures

1. Introduction

The current economic financial crisis in Europe has shown that no country is safe from business cycle downturns. As Claessens and Kose (2013: 3) mention “they hit small and large countries as well as poor and rich ones. They can have domestic or external origins, and stem from private or public sectors. They come in different shapes and sizes, evolve over time into different forms, and can rapidly spread across borders. They often require immediate and comprehensive policy responses, call for major changes in financial sector and fiscal policies, and can necessitate global coordination of policies.”

Despite the harshness associated to economic crises, particularly the most recent one which emerged in 2008, governments might nevertheless see them as an opportunity to enhance economies’ long-term potential through investment in innovation related activities, most notably Research and Development (R&D) (OECD, 2009).

According to Makkonen (2013), governments usually adopted two contrasting strategies regarding public innovation investment: pro-cyclical and counter-cyclical strategies. In the first case, the innovation expenditures follow the path of the relative variation in (real) gross domestic product (GDP), decreasing when there is an economic downturn (a fall in real GDP) and increasing in expansions (increases in real GDP). This is usually rationalized by the decrease in resources available in times of crises and/or depressions. In the counter-cycle hypothesis, public investment in innovation activities follows an opposite trend to that of the GDP, rising in times of stringency.

Some authors underline the relevance of R&D, namely, public R&D, for new discoveries and, ultimately, countries’ economic growth. For instance, Markovich (2012: 1), stressing the innovation mechanism, argues that “R&D investment helps develop new products and services that drive growth, create jobs, and improve the national welfare.” Focusing on the productivity mechanism, Guellec and Potterie (2001) underline the importance of R&D for economic growth stating that governments should provide appropriate funding for R&D performed in the public sector, in particular the higher education sector. In a similar fashion to Markovich (2012), Trajtenberg (1990) had already referred that investment in R&D was a key strategy to secure technological potential and therefore, innovation and economic growth.

More recently, Makkonen (2013) analyzed the impact of the economic crisis in the public R&D investment in EU27 countries. He concluded that the economic crisis affected the most new EU countries and those in the south of Europe. Additionally, although some countries still continued to invest in R&D, he showed that the majority of the European Union countries followed the pro-cyclical approach.

Despite Makkonen's (2013) important contribution, it still remains to be assessed whether economic crises affected not only the amount of (public) R&D but also its type; in other words, whether the distribution between basic and applied R&D varied over the period in analysis.

Indeed, a hot debate exists whether countries should emphasize more basic R&D or applied R&D. Oosterlinck et al. (2002) state that in the past basic and applied research were two different activities, but nowadays that division is very week and sometimes artificial. Although recognizing that often basic research is considered as a waste of money from taxpayer's point of view, Sherman (1998) points that basic and applied research activities have the same importance and the attempting to maintain a balance between them requires vision, intuition, imagination, and independence.

Nowadays, both basic and applied researchers face challenges in justifying their work. On the one hand, basic researchers must justify spending taxpayer money on work that cannot be guaranteed to result in a useful application (at least in a short, medium term span). As mentioned by Stemwedel (2006), in funding basic research, we are really gambling on the discovery of lots of good stuff that really will be of practical benefit to the public. On the other hand, applied researchers are able to explicitly state how their research will benefit society, but doing that they tend to establish the limits of their work by showing how their research will solve a specific problem (Landsheer, 2013).

So basic research has the potential to transform society but with low probability, in ways that cannot be predicted, while applied research has a benefit that can be easily predicted, but it is almost guaranteed that will not involve a big innovation breakthrough.

Aiming to contribute to the clarification of this debate, in the present dissertation we analyze the time paths of the weight of basic R&D (in total R&D) for 14 EU countries (for the remaining relevant data was not available), aiming at assessing whether the time series before (2003-2008) and after (2009-2012) the economic crisis changed their path. Summing up, we relate the ration of basic R&D in total R&D with countries' business cycle (reflected by the annual average growth rate of real GDP per capita).

The business cycle is the pattern of expansion, contraction and recovery in the economy. In general, the business cycle is measured and tracked in terms of Gross Domestic Product (GDP) and unemployment – GDP rises (its growth rate is positive) and unemployment shrinks during expansion phases, while reversing in periods of recession. Wherever one starts in the cycle, the economy is observed to go through four periods – expansion, peak, contraction and trough.

We seek to answer the following research question: Did the 2009 economic crisis impact on the weight of basic R&D investment in the EU countries?

In order to answer this question, we undertake an exploratory and descriptive analysis of the times series for basic R&D for the selected EU countries. Based on the patterns observed, we categorize countries according to their basic R&D paths and relate that with their innovative performance.

In terms of structure this dissertation is organized as follows. Next section provides a literature review on R&D and countries' performance. Then, in Section 3, the methodology of the study is described. The results are detailed in Section 4. Finally Section 5 discusses the results and highlights the main outcomes of the study as well as its policy implications and limitations.

2. Literature review

2.1. Main concepts

For a clear understanding of the present study, it is important to present the main definitions it involves, most notably R&D, and basic and applied research. For that purpose we resort to the Frascati Manual (OECD, 2002), which presents the methodology for collecting and using R&D statistics and it defines R&D as follows:

> Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications (OECD, 2002: 31).

Regarding basic research, the Frascati Manual defines it as an "experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, *without any particular application or use in view*" (OECD, 2002: 31, emphasis in italics added). Vannevar (1945) also says that basic research provides scientific capital, from which practical applications must be drawn. New products or services do not appear full grown, they are based in principles and conceptions developed in basic research. More recently, Markovich (2012) points that basic or pure research does not have a commercial objective but instead is focused on developing new principles or theories.

In contrast, applied research targets a well-defined and specific goal. It "is … original investigation undertaken in order to acquire new knowledge, [being] directed primarily towards a specific practical aim or objective" (OECD, 2002: 31). For the National Science Foundation (NSF) applied research is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met (NSF, 2010).

Roll-Hansen (2009: 5), also mentioned that applied research entails a "…contribution to the solution of specific practical problems… funded by government agencies, private firms, non-governmental interest organizations, to further their respective purposes in terms of social and medical improvements, economic profitability, ideological and political acclaim."

2.2. Relation between R&D and countries' innovation performance and economic growth

R&D is accepted to be the main engine of long-run economic growth in Europe and worldwide countries (European Commission, 2009). This relation between R&D and countries' economic growth can happen at several levels (organizational, local, regional and national levels) and through distinct mechanisms (e.g., local/regional/sector spillovers, human capital, Foreign Direct Investment (FDI), collaborations).

R&D can be public or private funded (Government/Private Firms) and each part promotes economic growth in a particular way (Dinges et al., 2007). Usually, it is considered that private R&D has the largest business impact because it is primary undertake to gain knowledge for rapidly product / service commercialization. However, it is also recognized that private sector on its own does not commit enough resources both in levels and type of R&D that would optimize society's welfare, so public R&D goes often to areas where time or quick economic returns are not the main objective, areas where private firms do not have the means to invest or do not want to take any risks. Without these public or public and private partnerships R&D investment economic growth is doomed (David et al., 2000).

From a geographic point of view, R&D institutions such as Universities, Labs, and Research Centers can have major economic impacts on the places where they are located. Licht and Siegel (2006) state that the type of surrounding institutions affects innovative and entrepreneurial activities. Also Baumol (1990) and Nee (1996) mentioned that R&D institutions have a huge influence in society's behavior to produce more or less economic productive activities.

Compared to foreign firms, domestic firms tend to be less endowed in capability enhancing elements (human capital and R&D) and are in general less productive (Teixeira and Lehmann, 2014). Thus, FDI is viewed, in general, by governments as a source for enhancing a country's innovation capabilities and in this way achieve higher economic growth (Teixeira and Wei, 2012). Indeed, since the early 80's government policymakers create tax incentives or subsidies in order to bring multinational corporations (MNCs) to their countries (Azman-Saini et al., 2010). As stated by Borensztein et al. (1998), MNCs are among the most technologically advanced firms, as they are responsible for a large part of the world's R&D expenditures. Thus, through

FDI the recipient countries are granted instant access to new technology that may benefit those receiving the foreign capital, and also other firms located in the host country, boosting countries' economic growth prospects.

Human capital is also an important factor to countries economic growth and R&D investments have an intimate relation with it. Mathur (1999) concludes that human capital stimulates growth and development directly as well as indirectly through its impact on the knowledge stock (R&D) of the region. Focusing on Portugal over forty decades (1960-2001), Teixeira and Fortuna (2010: 335) demonstrated that the indirect impact (by means of machinery and equipment imports) of the internal R&D efforts on Portuguese total factor productivity was "tremendous".

Continued advances in R&D and technology are crucial to ensuring and increasing countries economic growth and while returns to a firm from investing in R&D are high, returns to society tend to be even higher as new ideas are applied to areas far beyond what the innovator initially imagined (OECD, 2008).

2.3. The type of R&D (basic vs applied) and countries' economic growth: main arguments in debate

In today's competitive world, no country can progress without conducting and utilizing scientific research (European Commission, 2014). The importance of research may vary according to kind, namely in the case of basic and applied. They are both, however, important sources of knowledge-generation, being closely interlinked in the form of an R&D cycle, which following a series of steps becomes the source of new knowledge, generating new products and processes (Roux et al., 2006).

For Khan et al. (2007) the increasing gap between development of developed countries and most developing countries can be attributed to a number of factors. One of these factors is the extremely important role of scientific (basic) and technological (applied) research which cannot be overlooked.

It is no hidden fact that the developed countries of the world have been investing substantial funds and resources for scientific research and development, which has resulted in their current economic strength (Jehangir and Qureshi, 2007).

The timescale involved in basic vs applied research is very different (decades vs very short periods of time) which can have a distinct impacts on countries economic growth.

The debate starts here. Should countries apply public expenditures in applied research, giving a boost to economy by creating new products / services? Or should they apply public expenditures in basic research and create a solid base of knowledge for future generations and not only for the next 3 or 4 years?

This differential nature of the roles played by basic and applied research in the economy growth process has not yet been completely explored, and many related questions remain to be answered creating and promoting a debate between scholars, scientists and researchers (Akcigit et al., 2014). From this debate it aroused three different positions: 1) those who state that basic research is the fundamental base for economic growth; 2) those who state that basic and applied research are complementary; and 3) those that state that applied research promotes the most economic growth.

Starting with basic research the Aarhus Declaration on Excellence (2011) argues that providing more money for the scientific community to spend on basic research is the only way to guarantee the health of the research and higher education system and therefore economic prosperity. Also Khan et al. (2007: 28) state that "…basic research should be supported by governments, as their first priority compared to funding of applied research…", and that "any new innovation will not be successful until it has a solid ground, based on scientific knowledge". Butt (2007) also considers that basic research is the key element in any nation's growth.

Supporting the complementary (basic and applied research) position, Akcigit et al. (2014) concludes that basic and applied research investments are complementary. In particular, the higher public basic research investment encourages firms to invest more in applied research. Also Zakri and Pisupati (2007) state that worldwide economies have a little than they can gain from either favoring basic or applied research. For these authors society needs of both basic and applied research and the assurance of the correct balance and support to carry on the research is critical and will depend on basic research being relevant and flexible and applied research being responsive. In developing countries, as stated by Mustanser and Qureshi (2007), it is a current need to strengthen scientific knowledge both in the basic sciences as well as applied technical sciences and that a proper mix of basic and applied research can result in significant enhancement of local economies, specifically, through creation of high quality jobs and revenues for R&D institutions, universities and above all to the society.

There are also those who state the huge benefits when supporting applied research in detriment of basic research. Qazi et al. (2007) state that due to increasing international competition, it is important for a country to develop the scientific ideas (basic research) into marketable products (applied research) very early. Governments and universities are also revising their visions of research and related missions, giving a major importance to applied research. The National Science Foundation (NSF), a major funder of university research, is moving to commit more resources to applied research.

3. Methodology of the study

In order to properly answer all the main questions mention earlier, we adopt a quantitative research approach. It allows us to describe the characteristics of a given situation, measuring numerically the possible hypotheses for a given problem / research. This methodology is specially designed to generate accurate and reliable measures permitting statistical analysis such as the one we proposed to do (Moghaddam and Moballeghi, 2008).

Guided by the study by Makkonen (2013), we obtain our data from the databases of OECD (2000–2012). Additionally, we undertake a deeper exploratory and descriptive analysis of the times series for basic R&D for each EU countries, for which data was available (14 countries), covering the period (2003-2012) that includes the most recent European economic crisis. Then, we correlate the patterns observed in basic R&D with countries' growth cycle by groups of innovative performance. The analysis is done in three periods – before the crisis (2003-2008); after the crisis (2009-2013) and the whole period (2003-2013).

Table 1: The relevant variables and indicators for the empirical analysis

Variables	Indicators/definition	Source
R&D	Research and development expenditure is the money spent on creative work undertaken on a systematic basis to increase the stock of knowledge and the use of this knowledge to devise new applications. It covers three activities: basic research, applied research, and experimental development.	https://stats.oecd.org/glossary/detail.asp?ID=3111
Basic R&D	Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.	http://stats.oecd.org/glossary/detail.asp?ID=192
GDP per capita	Gross Domestic Product (GDP) per capita is a core indicator of economic performance and commonly used as a broad measure of average living standards or economic well-being.	http://www.oecd-ilibrary.org/sites/9789264067981-en/01/03/index.html?itemId=/content/chapter/9789264075108-5-en
Real GDP per capita growth	Computed as the rate of growth of nominal GDP per capita minus the inflation rate (based on the Harmonised Indices of Consumer Prices (HICPs))	https://data.oecd.org/gdp/gross-domestic-product-gdp.htm http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00118&plugin=1
R&D intensity	R&D intensity (R&D expenditure as a percentage of GDP) is used as an indicator of an economy's relative degree of investment in generating new knowledge.	http://www.oecd-ilibrary.org/sites/sti_scoreboard-2011-en/02/05/index.html?itemId=/content/chapter/sti_scoreboard-2011-16-en
Weight of basic R&D	Ration of Basic R&D in total R&D.	

4. Empirical analysis

4.1. General trends in R&D intensity and weight of basic R&D

Over the past decades, the economic benefits of R&D spending have become more widely discussed and studied, the number of papers related to this subject is very large, and claimed that R&D has contributed for economic growth in many countries (Jehangir and Qureshi, 2007; European Commission, 2009).

At the European level (EU28), the percentage of the GDP allocate to R&D (R&D intensity) has been increasing since 1999 (cf. Figure 1), observing a higher growth from 2007 to 2009, just well before the beginning of the European/World financial crisis (October 2008). Between 2009 and 2010 it decreased but since that date it is increasing although at a slower rate than in the previous periods.

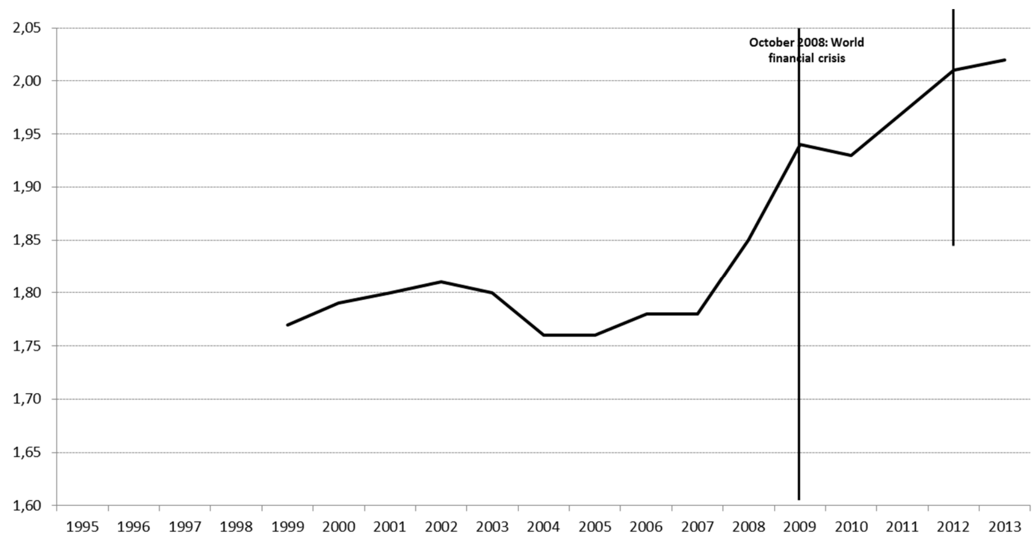

Figure 1: The evolution of total research and development (in % of GDP) in the European Union (EU28), 1999 – 2013

Source: OECD (2015), Gross domestic spending on R&D, in web site, accessed on June 08, 2015.

This evidence, however, might hide a lot of distinct behaviors among EU member states. To the best of our knowledge no analysis exists regarding the evolution of R&D intensity (R&D in total GDP) and the weight of basic R&D for each member state and the extent to which such eventual distinct behaviors are relate to the country's business cycle and innovation performance.

According to the Innovation Union Scoreboard (2014), the member states can be categorized into four different performance groups (by decreasing order of innovation performance): Innovation Leaders; Innovation Followers; Moderate Innovators; and Modest Innovators (see Table 2).

Table 2: EU28 countries by innovation performance

Innovation Leaders	Innovation Followers	Moderate Innovators	Modest Innovators
Denmark (DK)	Austria (AT)	Croatia (HR)	Bulgaria (BG)
Finland (FI)	Belgium (BE)	Czech Republic (CZ)	Latvia (LV)
Germany (DE)	Cyprus (CY)	Greece (EL)	Romania (RO)
Sweden (SE)	Estonia (EE)	Hungary (HU)	
	France (FR)	Italy (IT)	
	Ireland (IE)	Lithuania (LT)	
	Luxembourg (LU)	Malta (MT)	
	Netherlands (NL)	Poland (PL)	
	Slovenia (SI)	Portugal (PT)	
	United Kingdom (UK)	Slovakia (SK)	
		Spain (ES)	

Note: Grey color depicts countries which do not have data available for basic R&D and thus were not included in the analysis.
Source: European Commission, Innovation Union Scoreboard 2014, Brussels, 2014.

In the next section a detailed analysis of each member state according to its innovation performance category is undertaken. The aim is twofold. First, to establish whether R&D intensity and the weight of basic R&D in total R&D presents a pro or counter cycle evolution (before and after the international financial crisis), and to assess whether there exists some common pattern between countries innovation performance and the evolution of the basic R&D in total R&D.[1]

4.2. R&D intensity and the weight of basic R&D in total R&D before and after the international financial crisis by countries' innovation performance groups

4.2.1. Innovation Leaders

The first group of Innovation leaders includes Member States in which the innovation performance is well above that of the EU, i.e. more than 20% above the EU average. These are Denmark, Finland, Germany and Sweden. However, we are only capable of analyzing Denmark as the remaining countries do not possess data for basic R&D.

Denmark

Over the period in analysis (2003-2012) the average growth rate of the GDP per capita (constant prices) was -0.2%.[2] Between 2003 and 2008 it grew on average 0.1%/year, in

[1] There are several countries - Finland, Germany, Sweden, Belgium, Cyprus, Luxembourg, Netherlands, Croatia, Greece, Lithuania, Malta, Bulgaria, Latvia, Romania - that do not have data for basic R&D. Thus, they were not included in the present study.

[2] We decided to consider the GDP per capita instead of the GDP in order to take into account the distinct evolutions of countries' population.

2009 real GDP per capita collapsed (-4.1%), registering also a negative annual average growth rate of the GDP per capita of -0.4% in period after the world financial crisis (2009-2012).

Comparing the economic cycle with the evolution of R&D intensity, we observe that Denmark presents a counter-cyclical strategy, that is, when the annual growth rate of the real GDP per capita is slowing down the investment is R&D (as % of the GDP) is growing (Table 3).

Table 3: Denmark – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	0.1	-0.4	-0.2
R&D intensity (total R&D in GDP)	2.47	3.00	2.77
Weight of basic R&D (in total R&D)	16.9	18.3	17.7

Regarding the evolution of the weight of basic R&D in total R&D (Figure 2), we observe that the investment in basic R&D decreases very rapidly between 2005 until 2007, from 19.1% down to 13.0%. Then from 2007 until 2010 it increases to the same value of 2005. From 2010 on, it presented a slightly decrease to 18.4%. Regarding the growth of real GDP per capita, Denmark experienced an expansion from 2003 to 2007 and then a sudden and strong decrease in 2009. Despite the increases in the GDP per capital after that date the growth rate slowed down compared to its pre financial crises figures.

In terms of pro/counter cycle, it is apparent that before the financial crises basic R&D weight is evolving in counter cycle presenting a decreasing trend when GDP pc growth is increasing (the Pearson correlation coefficient is high and negative: -0.616). In the crisis aftermath basic R&D weight mimics GDP pc growth path, that is, is pro cycle (the Pearson correlation coefficient is high and positive: +0.890) – after an increase between 2009 and 2010, the slowdown in GDP pc growth afterwards is accompanied by a decrease in the weight of basic R&D (in total R&D).

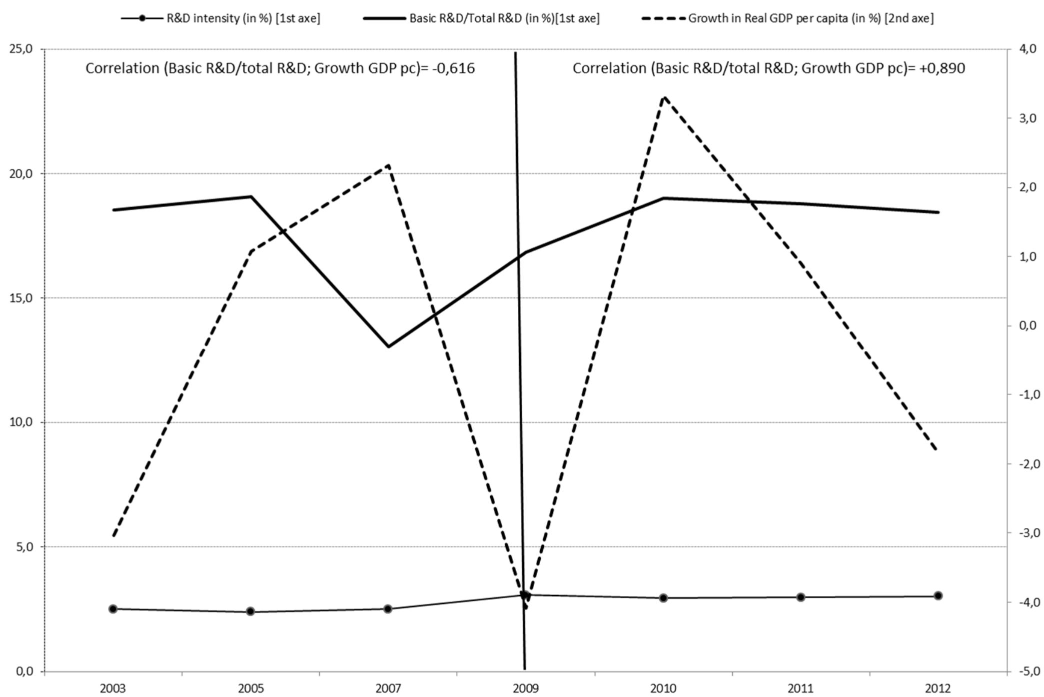

Figure 2: Economic performance of Denmark 2003 – 2012

Note: R&D by type (basic vs applied) is only available in a bi-annual basis.

Source: *OECD (2015),* Main Science and Technology Indicators.

Notwithstanding what correlations show, on average, the basic R&D in total R&D after the crisis is higher than the corresponding figure before the crisis. This means that Denmark succeed, despite the downturn in the economic cycle, to maintain and even reinforce both the R&D intensity and the weight of basic R&D in total R&D.

4.2.2. Innovation Followers

The second group, the Innovation followers, includes 10 Member States with a performance close to that of the EU average i.e. less than 20% above, or more than 90% of the EU average: Austria, Belgium, Cyprus, Estonia, France, Ireland, Luxembourg, Netherlands, Slovenia and the UK. Four countries (Belgium, Cyprus, Luxembourg, and the Netherlands) were not analyzed due to data unavailability.

Austria

Over the period in analysis (2003-2011) the average growth rate of the constant GDP per capita was 2.5%. Between 2002 and 2007 it grew 3.7 %/year, whereas in the subsequent period (2009-2011), the annual average growth rate of the GDP per capita slowed down to 0.0%, the main reason for this slowdown is the 2009 GDP per capital, when it collapsed presenting a growth rate of -1.6%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Austria has a counter-cyclical evolution: a decrease in GDP per capita was accompanied by an increase in the R&D intensity.

In the time interval of 2006 to 2009, Austria had a decrease in its GDP per capita. But, even so the investment in R&D was stable and rising during this period. After the financial crisis (2009 – 2013) the R&D intensity presents the highest values (2.65%). This result allow us to conclude that even during economy downturns, Austria still supports R&D in order to boost economy.

Table 4: Austria – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2007	After the financial crisis 2009 - 2011	2002 - 2011
Real GDP per capita growth	3.7	0.0	2.5
R&D intensity (total R&D in GDP)	2.26	2.65	2.39
Weight of basic R&D (in total R&D)	17.3	18.3	17.8

As for the weight of basic R&D in the total R&D, we can observe (Figure 3) that from 2009 to 2011 it increases when compared with 2003-2007. The weight of basic R&D in total R&D after the crisis is higher than the corresponding figure before the crisis (18.3% versus 17.3%, respectively as average value).

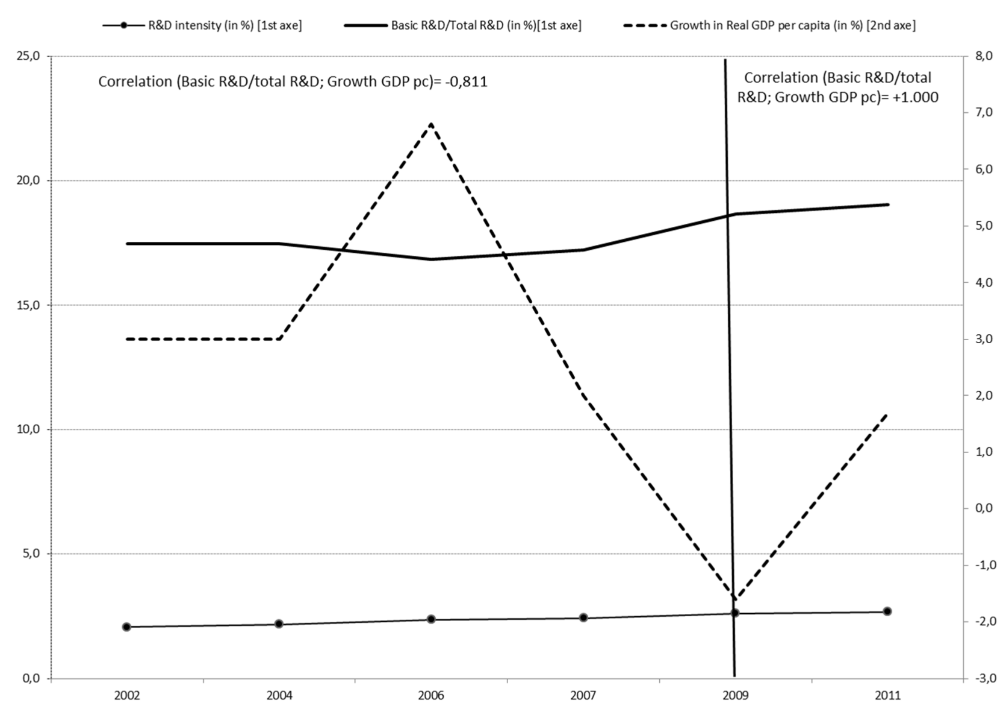

Figure 3: Economic performance of Austria 2002 – 2011

Note: Total R&D is only available from 2002 to 2011 in 2 year interval.

Source: *OECD (2015),* Main Science and Technology Indicators

In terms of pro/counter cycle, it is apparent that before the financial crises basic R&D weight is evolving in a light counter cycle presenting a decreasing trend when GDP pc growth is increasing. In the period of 2006 to 2009 it is noticeable that the basic R&D increases at the same time the GDP per capita slows down (-1.6% in 2009), pointing clearly to a counter cycle strategy (the Pearson correlation coefficient is high and negative: -0.811). After that period (in 2009-2011), the basic R&D weight is pro-cycle, increasing with the increase in the GDP pc growth rate (the Pearson correlation coefficient is high and positive: +1.000).

Summing up, Austria succeed, despite the downturn in the economic cycle in 2009, to maintain and even reinforce both the R&D intensity and the weight of basic R&D in total R&D.

Estonia

Over the period in analysis (2005-2012), the average growth rate of the current GDP per capita was 2.3%. Between 2005 and 2008 it grew 5%/year, whereas in the subsequent period (2009-2012), the annual average growth rate observed was only -0.3%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Estonia has one of the highest GDP grow rates in this "Innovation Followers" group, but also has the biggest drop, starting in 2006 until 2009 it goes from 12.2% to -10.4%. However, the average investment in R&D (as percentage of GDP) increased from 1.09% in the period of 2005 – 2008 up to 1.87% in 2009 – 2013, so Estonia presents a counter-cycle strategy.

Table 5: Estonia – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2005 - 2008	After the financial crisis 2009 - 2012	2005 - 2012
Real GDP per capita growth	5.0	-0.3	2.3
R&D intensity (total R&D in GDP)	1.09	1.87	1.48
Weight of basic R&D (in total R&D)	27.4	23.7	25.6

As for the weight of basic R&D in the total R&D, we only have data for the time interval of 2005 – 2012. We can observe in Figure 4 that Basic R&D goes down from 2005 to 2007 and then started to increase (2007 – 2009) at the same time GDP per capita, after a small increase in (2005 – 2006), decreased until 2009 when it reaches the lowest annual growth rate of -10.4%. The beginning period is thus characterized by a pro cycle strategy, but the following years (2007 – 2009) present a clearly counter cycle evolution.

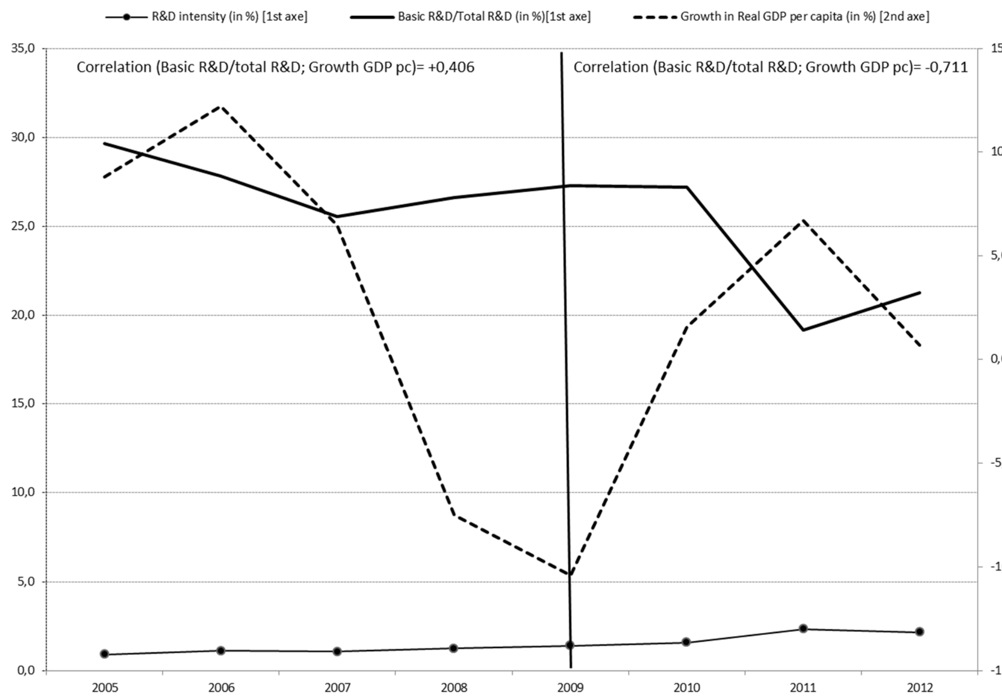

Figure 4: Economic performance of Estonia 2005 – 2012
Note: Total and Basic R&D are only available from 2005 to 2012
Source: *OECD (2015),* Main Science and Technology Indicators

Basic R&D in total R&D after the crisis is lower than the corresponding figure before the crisis. The correlations evidence that basic R&D between 2005 and 2009 was pro-cycle, decreasing with the decreases of GDP per capita growth rate, whereas between 2009 and 2012 was counter cycle, decreasing when GDP per capita growth increased (the Pearson correlation coefficient is high and negative: -0.711).

France

Over the period in analysis (2003-2012) the average growth rate of the current GDP per capita was 0.8%. Between 2003 and 2008 it grew 1.4%/year, in the next period (2009-2012), the annual average growth rate observed was 0%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that France presents a counter-cyclical strategy, that is, when the GDP per capita is slowing down the investment is R&D (as % of the GDP) is growing (Table 6).

Table 6: France – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	1.4	0.0	0.8
R&D intensity (total R&D in GDP)	2.06	2.20	2.12
Weight of basic R&D (in total R&D)	24.3	26.0	25.0

Comparing the economic cycle with the evolution of R&D intensity, we observe that France has a slight counter-cyclical strategy.

In 2009 during the economic crisis, GDP growth was very low (-1%) but besides that, the investment in R&D was stable during this period and in 2007 – 2009 the investment presented an increase from 2.02% (in 2007) to 2.21% (in 2009). So, even during economy downturns, France managed to reinforce the investment in R&D.

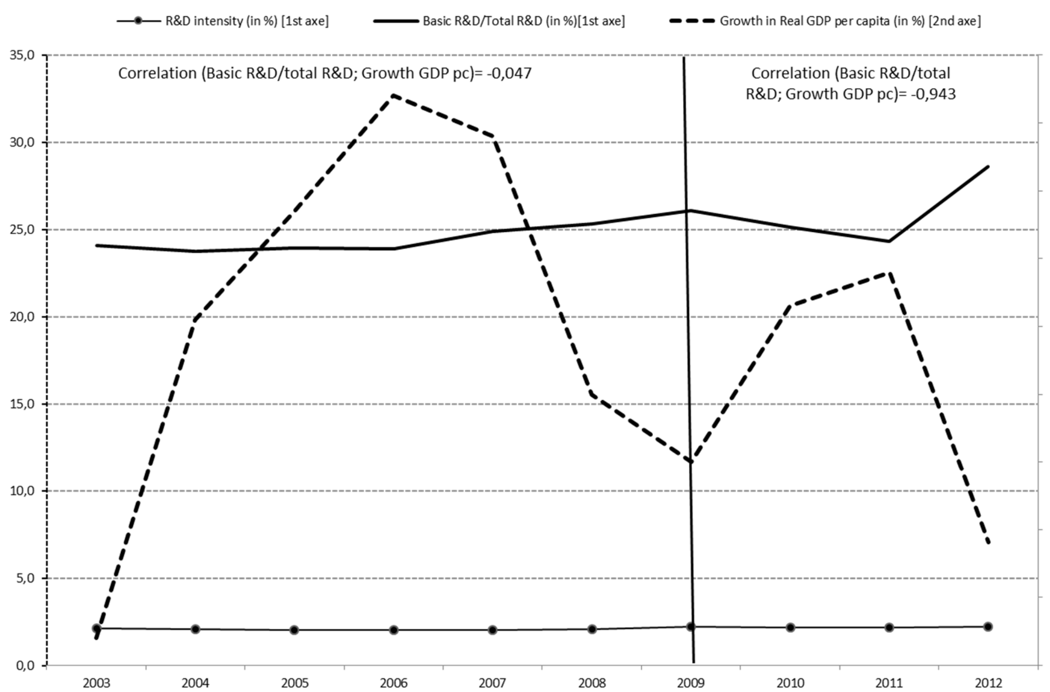

Figure 5: Economic performance of France 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Regarding the evolution of the weight of basic R&D in total R&D (Figure 5), we observe that the investment in Basic R&D is very stable from 2003 to 2006, growing a little above 25% from 2007 to 2009 at the same period GDP also increased, reaching the peak value of 4.4% in 2006, and decreasing very rapidly until 2009. So, even with little relevance, France was pursuing a counter cycle strategy (the Pearson correlation coefficient is low and negative: -0.047). In the period after the crisis GDP per capita increased again until 2011, then in 2012 went down. However, the increase of Basic R&D ration is notorious, reaching 26%, 1.7% more than in 2003– 2009, depicting a clear counter cycle strategy (the Pearson correlation coefficient is high and negative: -0.943). One might conjecture therefore that France during considers basic R&D and knowledge creation as a major advantage for exiting recession.

Ireland

Ireland was one of the countries which received economic assistance from the European Commission, the European Central Bank (ECB) and the International Monetary Fund (IMF) (the Troika), being one of the first countries to be hit by the financial turmoil that started in the US. Indeed, its real GDP per capita growth suffered a major downturn, not in 2009 but earlier, in 2007-2008 in the epicenter of the European and world economic crisis. Irish GDP growth for the period of 2003 to 2011 was 1.5%. Before the economic crisis (2003 – 2007), the average GDP per capita growth was 3.4%, but in the following period (2008 – 2011) was negative, -1.1%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Ireland, considering global averages, presents a counter-cycle strategy: the real GDP per capita growth rate is declining and the investment is R&D (as % of the GDP) is growing (see Table 7).

Table 7: Ireland – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2007	After the financial crisis 2008 - 2011	2003 - 2011
Real GDP per capita growth	3.4	-1.1	1.5
R&D intensity (total R&D in GDP)	1.19	1.54	1.35
Weight of basic R&D (in total R&D)	22.3	20.5	21.5

Regarding the evolution of the weight of basic R&D in total R&D (Figure 6), we observe that the investment in Basic R&D goes up from 2003 to 2005, at the same time GDP pc is also growing, then from 2005 to 2007 decreases and in 2007 – 2008 increases again to the highest value of 25%, just when GDP pc reaches the lowest value of -6.4%.

Looking at the correlation between GDP growth and the weight of basic R&D in total R&D (the Pearson correlation coefficient is high and positive: +0.813) it is apparent that before the financial crises basic R&D weight is evolving in pro cycle fashion, presenting an increasing trend when GDP pc growth is increasing. In the crisis aftermath (2008 – 2012) basic R&D weight presents an opposite trend to that of GDP per capita growth – i.e., evolves in a counter cycle strategy (the Pearson correlation coefficient is negative: -0.912).

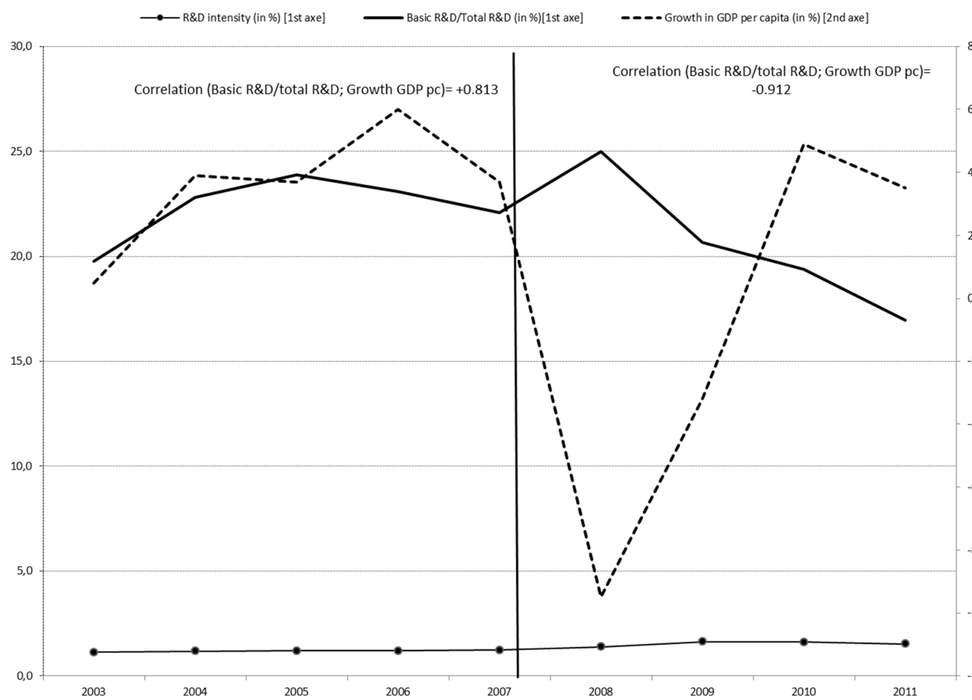

Figure 6: Economic performance of Ireland 2003 – 2011

Note: In Ireland the crisis started earlier than in the remaining countries due to the proximity links of its banking system with the one from the US.

Source: *OECD (2015),* Main Science and Technology Indicators

This means that Ireland, despite the downturn in the economic cycle, has reinforced the R&D intensity but put its emphasis on applied R&D at the expenses of basic R&D, which is mainly state financed and therefore suffered more with the austerity measures implemented.

Slovenia

Over the period in analysis (2003-2012) the average growth rate of the real GDP per capita was 0.5%. Between 2003 and 2008 it grew 2.7%/year, but in the subsequent period (2009-2012), the annual average growth rate observed was negative, -2.9%.

Table 8: Slovenia – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	2.7	-2.9	0.5
R&D intensity (total R&D in GDP)	1.43	2.22	1.75
Weight of basic R&D (in total R&D)	12.3	13.4	12.7

Comparing the economic cycle with the evolution of R&D intensity, we observe that Slovenia also has a counter-cycle strategy.

In the time interval of 2007 to 2009, Slovenia had a major drop in the GDP per capita going from 1.4% (2007) to -8.0% (2009). Notwithstanding, the investment in R&D was stable during this period and increased in the following years. So, even during economy downturns, Slovenia managed to sustain its R&D intensity.

As for the weight of basic R&D in total R&D we can observe that before the crisis (2003 – 2008) the path was up and down year after year, indicating a counter cycle strategy (the Pearson correlation coefficient is slightly negative: -0.071). After the crisis (2009 – 2012) when real GDP per capita started to recover and grew again, the weight of basic R&D started to decrease. From 2011 to 2012, real GDP per capita decreased again and basic R&D slightly increased (Figure 7).

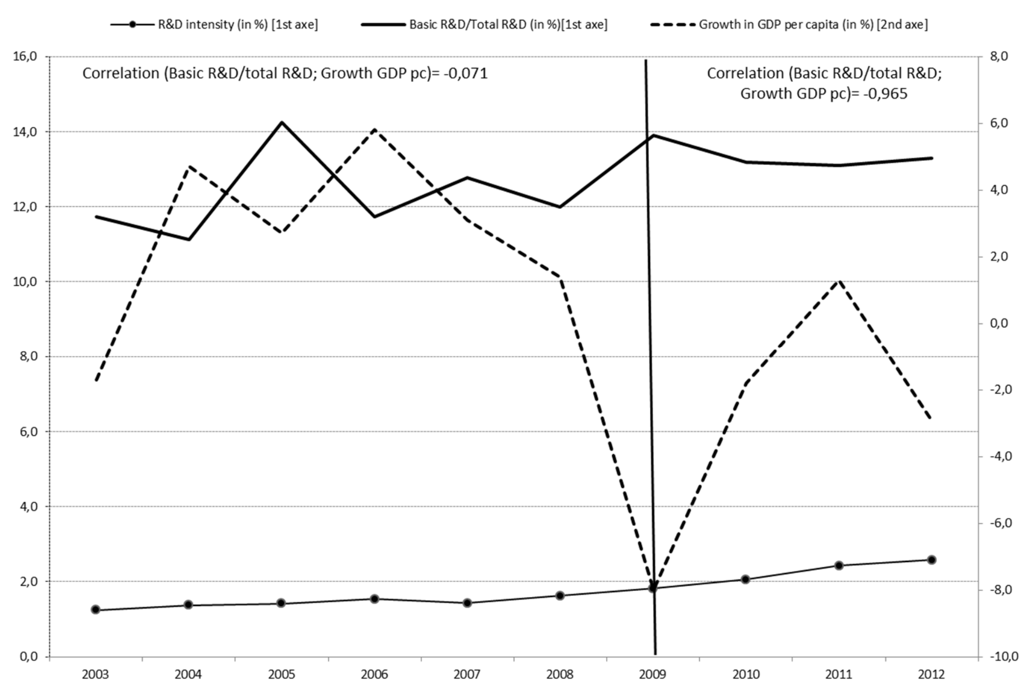

Figure 7: Economic performance of Slovenia 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

After the crisis Slovenia presented a clear counter cycle approach (the Pearson correlation coefficient is very high and negative: -0.965). We can conclude that Slovenia besides the real GDP per capita growth instability, before and after the crisis, was successful in increasing R&D intensity and maintaining the weight of basic R&D.

United Kingdom

Over the period in analysis (2007-2012) the average growth rate of the real GDP per capita was negative, -0.3%. Between 2007 and 2008 it grew 1.8%/year, but in 2009 GDP per capita suffered a major decline, presenting a noticeable negative growth (-6%), which resulted in a decrease in the average GDP per capita growth of -3.4% in the period after the financial crisis (2009-2012).

Comparing the economic cycle with the evolution of R&D intensity, we observe that United Kingdom presents a slight counter-cycle strategy, that is, even when GDP per capita is slowing down, the investment is R&D (as % of the GDP) remained almost stable (1.69%) - Table 9.

Table 9: United Kingdom – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2007 - 2008	After the financial crisis 2009 - 2012	2007 - 2012
Real GDP per capita growth	1.8	-3.4	-0.3
R&D intensity (total R&D in GDP)	1.66	1.69	1.67
Weight of basic R&D (in total R&D)	15.8	15.8	15.8

Regarding the evolution of the weight of basic R&D in total R&D we observe that the weight in basic R&D increases slightly in 2008 – 2009 at the same time GDP per capita growth drops from -2.8% down to -6.0%. Then from 2009 until 2011, the weight of basic R&D drops to 14.9% while the real GDP per capita growth presents a small recovery.

In terms of pro/counter cycle, on average the weight of basic R&D is clearly evolving in counter cycle presenting a decreasing trend when real GDP per capita growth is increasing in 2008 (the Pearson correlation coefficient is negative -1.000). In the crises aftermath basic R&D ration continues to evolve in the opposite way to real GDP pc growth. When real GDP pc growth started to recover (2009 – 2012), the ration of basic R&D was going down, even with a slight increase in 2012 (the Pearson correlation coefficient is high and negative: -0.735).

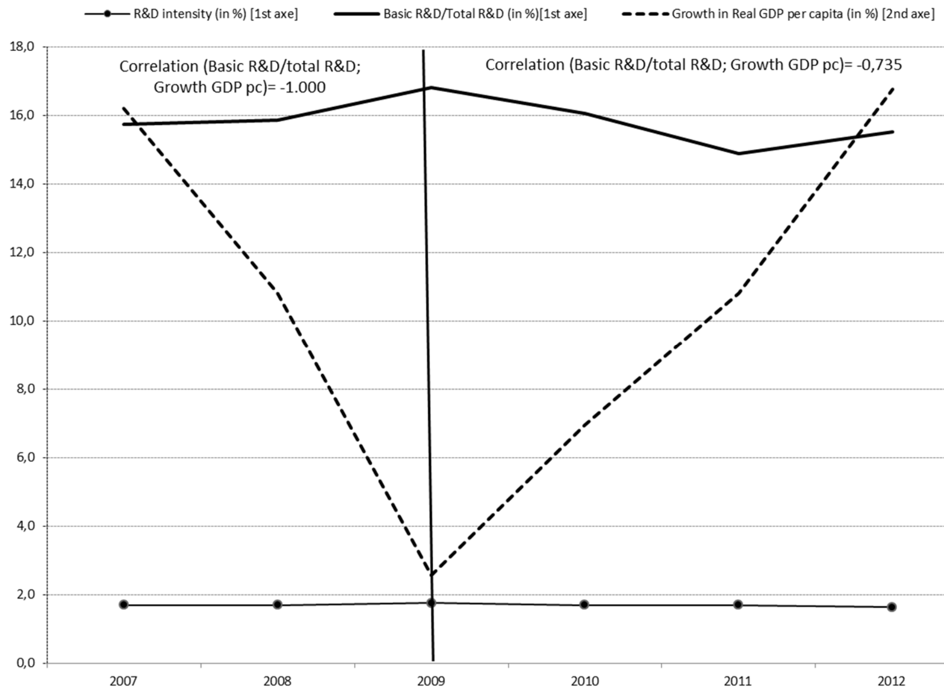

Figure 8: Economic performance of United Kingdom 2007 – 2012

Note: Basic R&D/Total R&D is only available from 2007 to 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Despite the downturn economic cycle the United Kingdom managed to maintain (even slightly increased) its R&D intensity and basic R&D ration.

4.2.3. Moderate Innovators

The third group of Moderate innovators includes Member States where the innovation performance is below that of the EU average at relative performance rates between 50% and 90% of the EU average. Croatia, Czech Republic, Greece, Hungary, Italy, Lithuania, Malta, Poland, Portugal, Slovakia and Spain belong to the group of Moderate innovators.

Czech Republic

For the period in analysis (2003-2012) the average growth rate of the current GDP per capita was 2.4%. Between 2003 and 2008 it grew 4.1%/year, as for the period after the crisis it went negative to -0.3%, also influenced by the 2009 slowdown (-1.0%).

Comparing the economic cycle with the evolution of R&D intensity, we observe that Czech Republic presents a counter-cycle strategy, because when the GDP per capita growth rate is slowing down the investment is R&D (as % of the GDP) is growing (Table 10).

Table 10: Czech Republic – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	4.1	-0.3	2.4
R&D intensity (total R&D in GDP)	1.21	1.50	1.32
Weight of basic R&D (in total R&D)	30.0	30.5	30.2

Regarding the evolution of the weight of basic R&D in total R&D we observe that the ration Basic R&D in total R&D was more or less stable before and after the crisis.

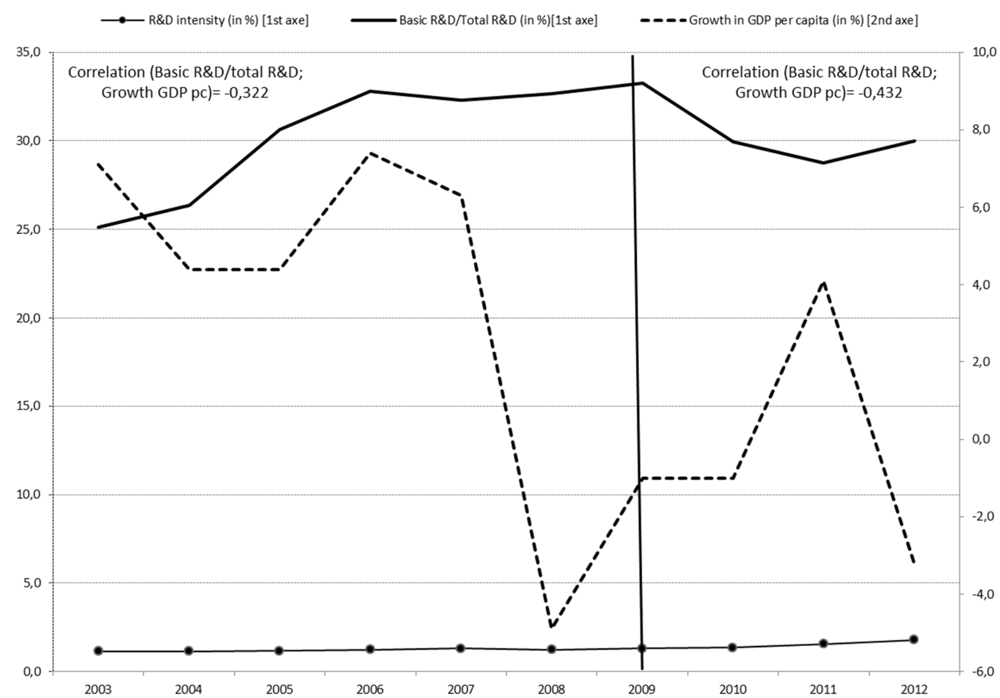

Figure 9: Economic performance of Czech Republic 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Source: *Eurostat (2015) (R&D Intensity)*

In terms of pro/counter cycle, in the first period (2003 – 2008) the evolution of the basic R&D ration was rather unstable: in 2003 – 2004 presented a counter cyclical trend, followed (2004 – 2006) by a pro cyclical, and then, in 2006 – 2008, again counter cyclical. So the correlation for this period is not very conclusive despite being negative (counter cycle) (the Pearson correlation coefficient is low and negative: -0.322).

After the crisis, on average the weight of R&D is evolving in counter cycle presenting a decreasing trend when real GDP pc growth is increasing (2009 – 2010) and increasing (2011 – 2012) when GDP pc dropped (the Pearson correlation coefficient is negative: -0.432).

Despite what correlations show, on average, the ration basic R&D in total R&D after the crisis is 0.5% higher than the corresponding figure before the crisis. This means that Czech Republic had some success in sustain basic R&D ration (and even reinforce both the R&D intensity) despite the downturn in the economic cycle.

Hungary

Over the period in analysis (2003-2012) the average growth rate of the real GDP per capita was -0.9%. Before the crisis (between 2003 and 2008) it grew 0.2%/year, and after the crisis (2009 and 2013) the average growth rate was negative, -2.5%.

Comparing the economic cycle with the evolution of R&D intensity, it is not easy to disentangle a clear cut path. However, analyzing the average values (Table 11), we may say that Hungary presents a counter-cycle strategy; that is, when the real GDP per capita is slowing down the investment is R&D (as % of the GDP) is growing.

Table 11: Hungary – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	0.2	-2.5	-0,9
R&D intensity (total R&D in GDP)	0.94	1.19	1.04
Weight of basic R&D (in total R&D)	26.5	21.2	24.4

Regarding the evolution of the weight of basic R&D in total R&D (Figure10), we observe that the investment in basic R&D decreases constantly since 2004 until 2012, from 33% down to 19.7%. Despite the increases in the real GDP per capita in 2006 and 2008, the weight of Basic R&D continued to slow down. Thus, Hungary follows a pro cycle approach before the crisis (the Pearson correlation coefficient is negative: -0.157) and a counter cycle approach after the crisis (the Pearson correlation coefficient is positive: +0.340).

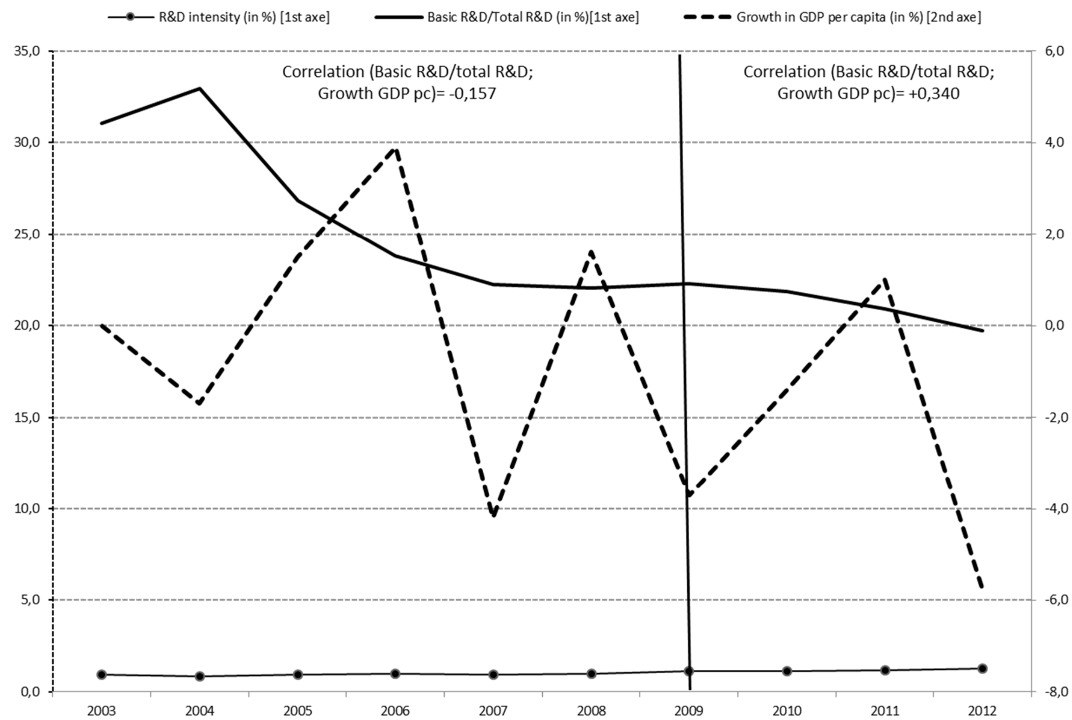

Figure 10: Economic performance of Hungary 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

On average, the basic R&D in total R&D after the crisis is lower than the corresponding figure before the crisis (cf. Table 11). This means that Hungary succeed, despite the downturn in the economic cycle, to reinforce R&D intensity but it saw its ration of basic R&D in total R&D diminished.

Italy

Over the period in analysis (2003-2012) the average growth rate of the real GDP per capita was 0.1%. Between 2003 and 2008 it grew 1.3%/year, in 2009 real GDP per capita, as observed in almost other analyzed countries, severely declined (-3.8%), which justifies the fall in the average of real GDP per capita growth (-1.9%) in period after the world financial crisis (2009-2012).

Comparing the economic cycle with the evolution of R&D intensity, we observe that Italy also presents a counter-cycle strategy, that is, even when real GDP per capita is slowing down as in 2009, the investment is R&D (as % of the GDP) went from 1.09% (in the period before the crisis) to 1.23% (in the period after the crisis) - Table 12.

Table 12: Italy – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	1.3	-1.9	0.1
R&D intensity (total R&D in GDP)	1.09	1.23	1.15
Weight of basic R&D (in total R&D)	27.2	25.0	26.3

Regarding the evolution of the weight of basic R&D in total R&D (Figure 11), we observe that the ration basic R&D starts to decrease in 2006 – 2007, then it increases a bit in 2008 and 2009, while real GDP pc drops immensely. After the crisis it goes down again, while real GDP pc growth starts to increase. Thus, Italy follows a pro cycle strategy before the crisis (the Pearson correlation coefficient is positive: +0.486) and a clear counter cycle approach after the crisis (the Pearson correlation coefficient is high and negative: -0.651).

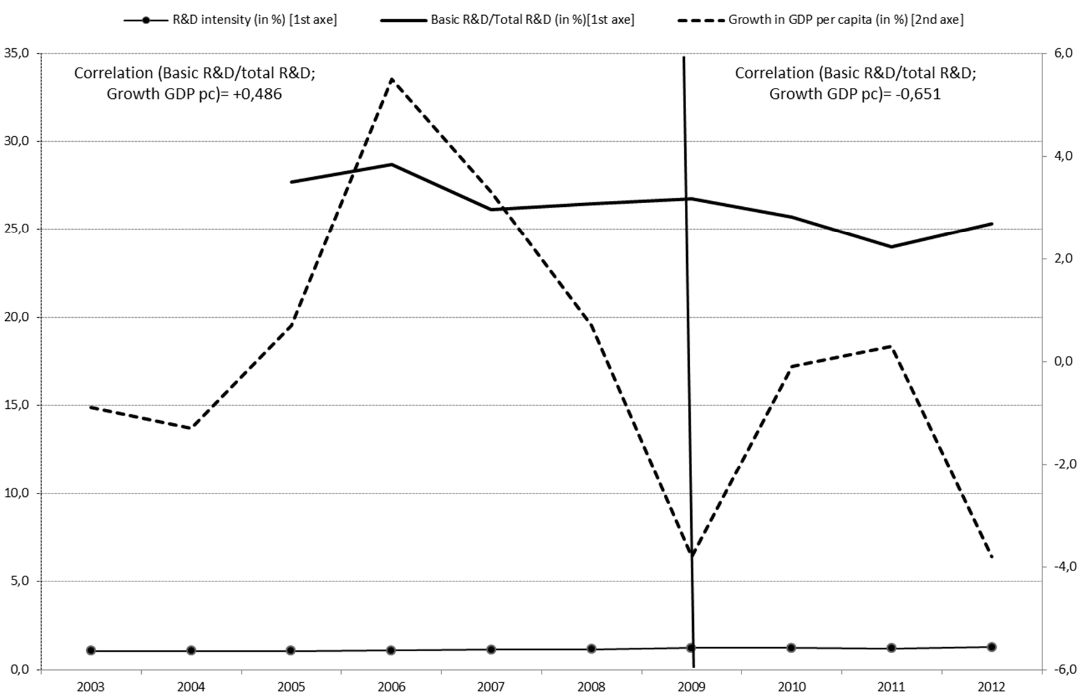

Figure 11: Economic performance of Italy 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Summing up, we verify that even in difficult economic times, Italy managed to sustain its R&D intensity but failed to avoid the decline in the ration of basic R&D.

Poland

Over the period in analysis (2003-2012) the average growth rate of the constant GDP per capita was 4.2%. Between 2003 and 2008 it grew 5.3%/year, but in the subsequent period (2009-2013), the annual average growth rate observed was 2.5%. From the countries analyzed above, the time period after the financial crises (2008 – 2012), used to present negative averages or near 0% GDP pc growth. Poland presents a different scenario, besides a major decrease in GDP pc caused by the crisis, they continue to have a good GDP pc growth rate, when compared with other European countries.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Poland in average also presents counter-cycle strategy , even with a small increase, but when the GDP per capita is slowing down the investment is R&D (as % of the GDP) is growing (Table 13).

Table 13: Poland – averages (in %) of the relevant indicators

Indicator	**Before financial crisis 2003 - 2008**	**After the financial crisis 2009 - 2012**	**2003 - 2012**
Real GDP per capita growth	5.3	2.5	4.2
R&D intensity (total R&D in GDP)	0.56	0.76	0.64
Weight of basic R&D (in total R&D)	38.0	37.8	37.9

Regarding the evolution of the weight of basic R&D in total R&D, we observe that the ration of Basic R&D is stable for the all-time, before and after the crisis. As we can see in Figure 12, real GDP per capita is very unstable in the period before the crisis, decreasing in 2004 – 2005, increasing in 2005 - 2007 and decreasing again in 2007 – 2009; however, the ration of basic R&D almost always does not follow this path and has an opposite trend (the Pearson correlation coefficient is negative: -0.501). After the crisis real GDP per capita growth has a small recover and basic R&D ration follows this path with the exception of the period 2011 – 2012 when real GDP per capita declines and basic R&D ration slightly increases. Anyway, after the crisis Poland presents a pro cycle approach (the Pearson correlation coefficient is positive: +0.515).

Poland despite the downturn in the economic cycle, also succeed to maintain and even reinforce the R&D intensity and maintaining the weight of basic R&D in total R&D. Although Polish R&D intensity is below 1% (average 2003 - 2012 = 0.64 %), we can notice that a large part of it is allocated to basic R&D (37.9%) (average 2003 – 2012).

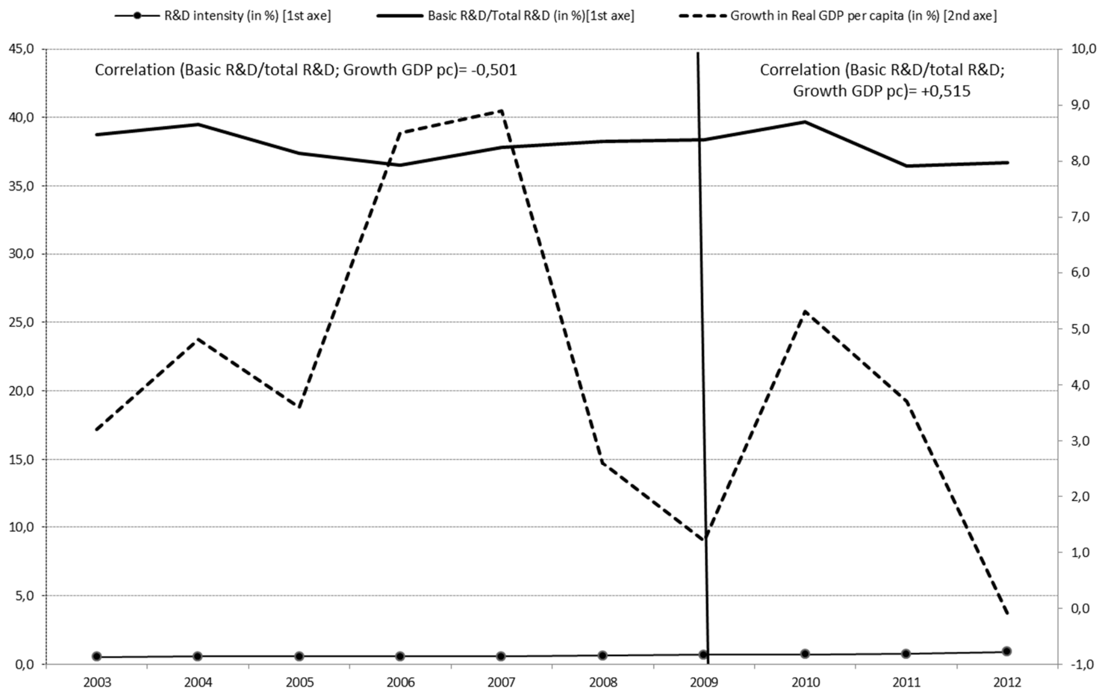

Figure 12: Economic performance of Poland 2003 – 2012
Source: *OECD (2015),* Main Science and Technology Indicators

Portugal

Similarly to Ireland, Portugal also experienced a financial intervention with the international economic assistance from Troika (the European Commission, the European Central Bank (ECB) and the International Monetary Fund (IMF)) as the concomitant austerity plan which aimed to decrease overall public expenditures and overcome public accounts deficit.

For the overall period in analysis (2003 to 2012), the real growth rate of the GDP was sluggish but positive (1.2%). In 2007-2008, it suffered a major decline. Before the economy crisis (2003 – 2008), Portuguese real GDP average growth rate was 2.5%, but in the period after the crisis (2009 – 2012), it was negative, -0.7%.

Portugal presents a clear counter-cycle strategy in terms of R&D intensity; that is, when the real GDP per capita growth rate is slowing down the investment is R&D (as % of the GDP) is growing (Table 14). Before the financial crisis, R&D intensity was 0.95%, whereas after the crisis it reached 1.48%.

Table 14: Portugal – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	2.5	-0.7	1.2
R&D intensity (total R&D in GDP)	0.95	1.48	1.16
Weight of basic R&D (in total R&D)	22.6	21.3	22.1

Regarding the evolution of the weight of basic R&D in total R&D, we observe that the basic R&D ration is, on average, about 22.1% in the overall period 2003 – 2012 period in analysis.

From 2005 to 2007 basic R&D ration was evolving in pro cyclical fashion (Figure 13) – real GDP pc growth rate was decreasing and basic R&D ration was decreasing too. After this period, and when financial crisis hit harder, basic R&D ration started to go up while real GDP pc growth rate accentuate its decline. In short, the Portuguese ration of basic R&D presented counter cycle strategy before the crisis (the Pearson correlation coefficient is negative: -0.155). After the crisis real GDP pc growth rate increased from 2009 to 2010 and then decreased from 2010 to 2011, increasing again in 2011 – 2012; basic R&D ration mimicked this path following a pro cycle approach (the Pearson correlation coefficient is high and positive: +0.856)

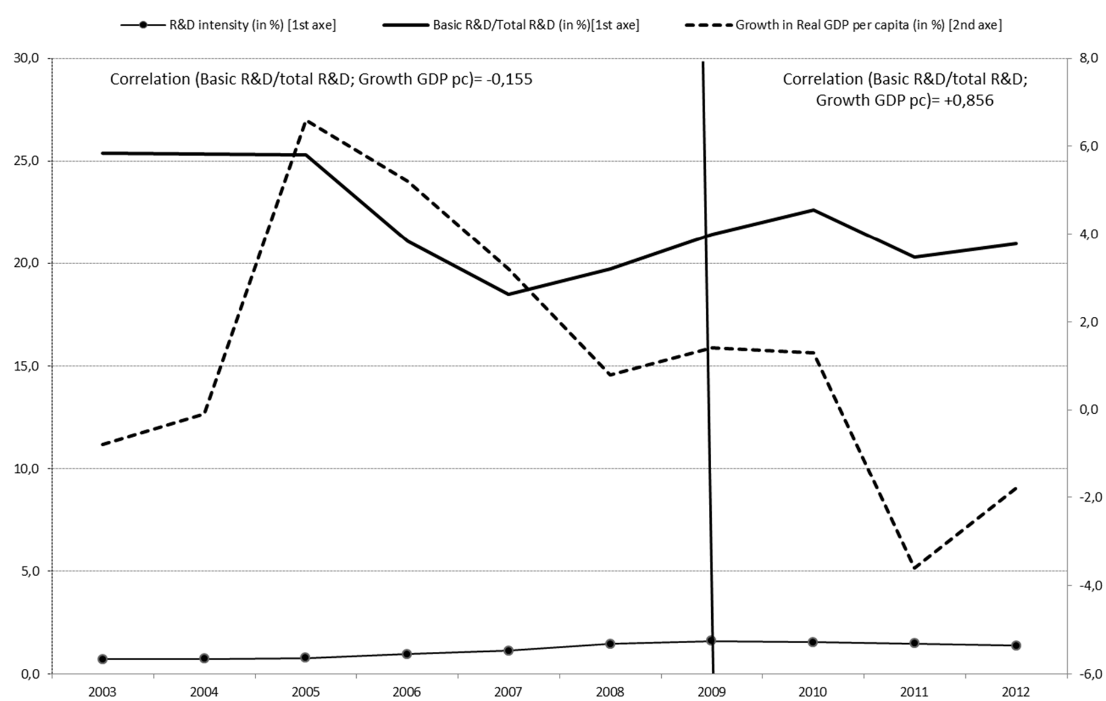

Figure 13: Economic performance of Portugal 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

On average, and as observed in Figure 13, the weight of basic R&D in total R&D after the crisis is smaller than the corresponding figure before the crisis, albeit it had increased during the financial crisis.

Slovakia

Over the period in analysis (2003-2012) the average growth rate of the constant GDP per capita was 3.2%. Between 2003 and 2008 it grew 5.5%/year, whereas in the subsequent period (2009-2012), the annual average growth rate observed was only 0.2%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Slovakia, along with Estonia, has one of the highest real GDP grow rates, but also one of the sharpest declines. In only one year (2009), real GDP pc growth rate went from 7% down to -3.6%. In that same period R&D intensity increased. Before the crisis Slovakia had an average R&D intensity of 0.49%, whereas after the crisis the figure went up to 0.64%.

Table 15: Slovakia – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	5.5	0.2	3.2
R&D intensity (total R&D in GDP)	0.49	0.64	0.55
Weight of basic R&D (in total R&D)	44.4	47.2	45.5

Regarding the weight of basic R&D in total R&D, we observe that Slovakia presents the highest ration among the countries in analysis (45.5%) for the whole period in analysis (Table 15). Despite the crisis, the ration increased, from 44.4% (2003-2008) up to 47.2% (2009 – 2012).

Before the crisis it is evident a pro cycle approach – basic R&D ratio follows closely the real GDP per capita growth rate (the Pearson correlation coefficient is high and positive: +0.780). After the financial crisis, Slovakia follows a counter cycle strategy – notwithstanding the decline in the real GDP per capita growth rate, basic R&D ration grew (Figure 14, the Pearson correlation coefficient is negtive: -0.265).

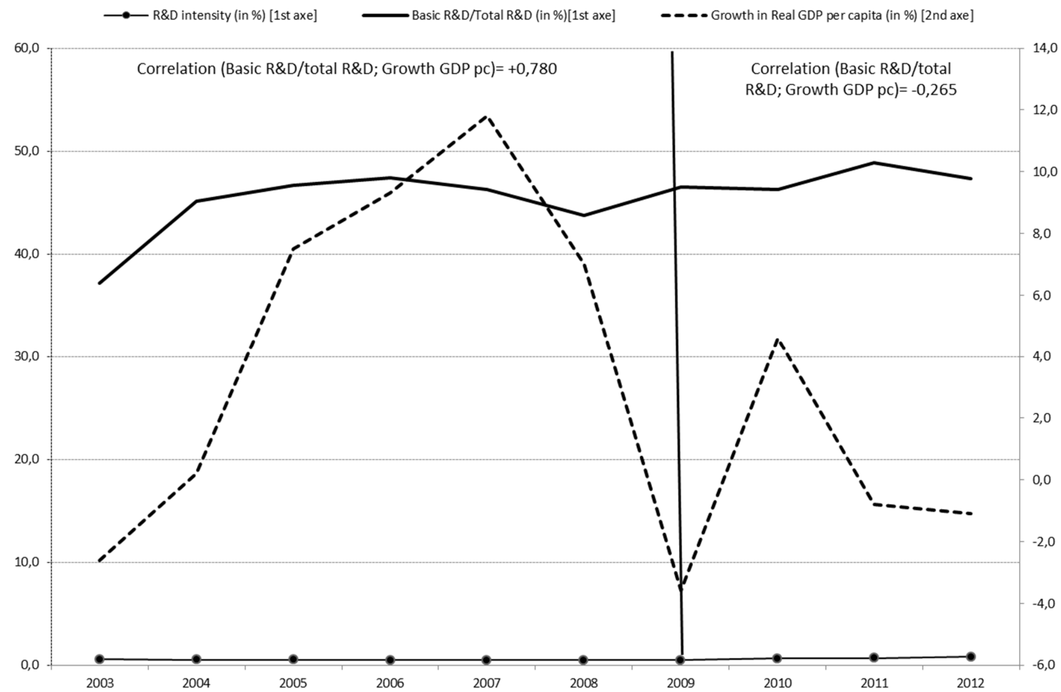

Figure 14: Economic performance of Slovakia 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Spain

Over the period in analysis (2003-2012) the average growth rate of the constant GDP per capita was low (0.2%). Between 2003 and 2008 it grew at a reasonable pace, 2.0%/year, whereas in the subsequent period (2009-2012), the annual average growth rate observed a dramatic fall, -2.5%.

Comparing the economic cycle with the evolution of R&D intensity, we observe that Spain has a counter cycle strategy because even when real GDP pc decreases (2009: -2.5%) R&D intensity grows.

Table 16: Spain – averages (in %) of the relevant indicators

Indicator	Before financial crisis 2003 - 2008	After the financial crisis 2009 - 2012	2003 - 2012
Real GDP per capita growth	2.0	-2.5	0.2
R&D intensity (total R&D in GDP)	1.15	1.32	1.22
Weight of basic R&D (in total R&D)	21.4	22.6	21.9

Regarding the weight of basic R&D in total R&D, we observe that it remained more or less constants with a slight increase from 21.4% to 22.6% (Table 16).

Spain followed a counter cycle approach before the crisis and since 2003 to 2006 – real GDP per capita growth rate grew and basic R&D ration slowed down. In contrast, from 2006 to 2009, when financial crisis had its biggest impact and real GDP per capita was negative (-2.5% in 2009), basic R&D ration increased (Figure 15 - the Pearson correlation coefficient is negative: -0.703).

After the crisis Spain followed a pro cycle strategy - real GDP per capita started to increase and basic R&D ration followed the same path (the Pearson correlation coefficient is high and positive: +0.824).

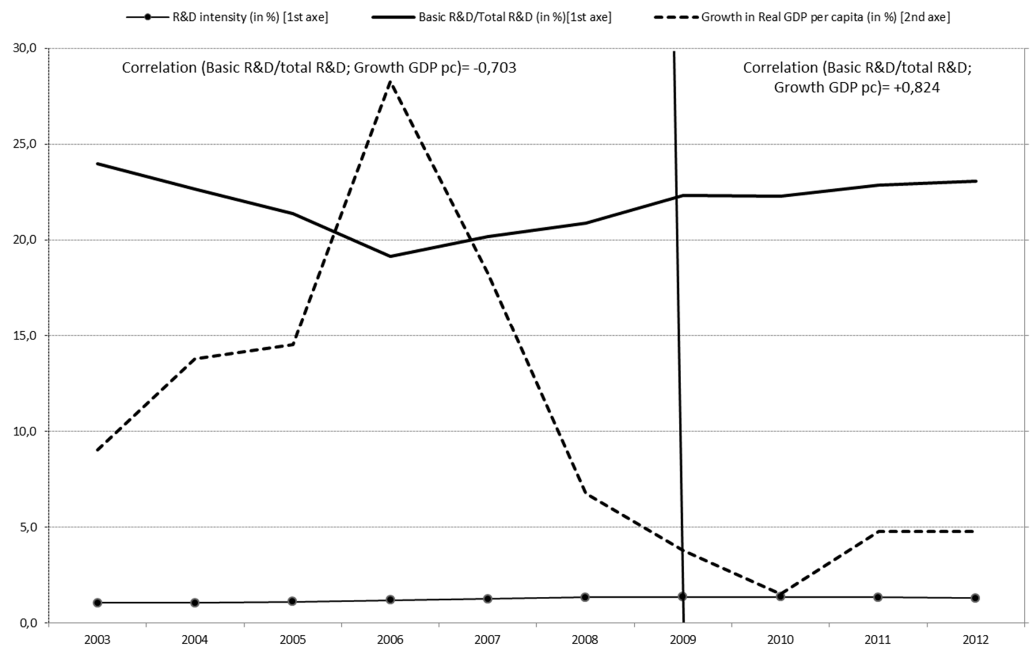

Figure 15: Economic performance of Spain 2003 – 2012

Source: *OECD (2015),* Main Science and Technology Indicators

Spain, as most of the southern Europe countries, suffered a big impact from the financial crisis and the downturn in the economic cycle was noticeable. Nevertheless, it succeed to maintain and even reinforce the R&D intensity and the weight of basic R&D in total R&D.

4.2.4. Modest Innovators

The fourth group of Modest Innovators includes Member States that show an innovation performance level well below that of the EU average, i.e. less than 50% of the EU average. This group includes Bulgaria, Latvia, and Romania. Unfortunately for this fourth group, data is not available which hampered the analysis.

∴

Attempting to summarize the main outcomes of the analysis undertook in this section, it is interesting to note that the groups of countries that present the highest innovation performance according to the 2014 European Innovation Scoreboard (Leaders and Followers) are associated with an increase in the weight of basic R&D in total R&D. The exceptions are Ireland and Estonia. The Irish case's evolution might be related to the austerity program that followed the Troika intervention with strong impact on public expenditures and, thus, on basic R&D whose main funding source is public outlays. In the moderate innovation group, the vast majority of countries presented a downward trend in the weight of basic R&D expenditure. The exception being Slovakia which saw its already huge share of basic R&D growing and Spain and Czech Republic that managed to maintain more or less the same share before and after the crisis.

Such outcome indicates that future catching up processes by moderate innovators to followers or leaders might be at risk as the former might lack the relevant basic knowledge to augment their potential for breakthrough innovations and thus risk to become even more distant from the technological frontier.

4.3. Basic R&D weight, innovation performance, and the business cycle: is there any link?

Regarding the first period (2003-2008), and as observed in Figure 16, there is a positive and significant association between the variation of the ration basic R&D in total R&D and the average growth rate of real GDP per capita. Thus, countries that over this period increased their share of basic R&D in total R&D have, on average, evidenced higher economic performances, or, in other words, were in an expansionary business cycle.

Interestingly, those countries that experienced higher positive variations in the ration basic R&D in total R&D were the ones that presented a high proportion of basic R&D in total R&D. This is the case of Czech Republic or Slovakia where basic R&D represents more than 25% of total R&D – for Czech Republic the figure was 30.2%, whereas for Slovakia de corresponding figure was 45.5% (average values for 2003-2012).

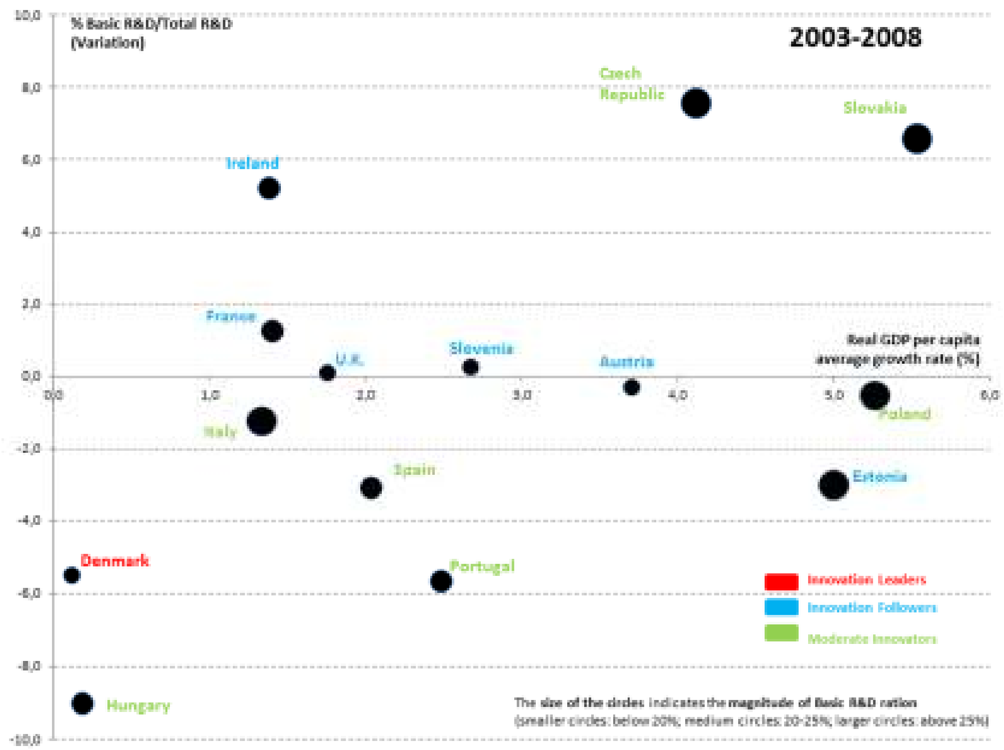

Figure 16: Relation between the variation of the Basic R&D in total R&D ration (%) and the Real GDP per capita annual average growth rate (%), 2003-2008

Note: In the case of Austria the period considered was 2002-2007 whereas for Estonia the period considered was 2005-2008.

No statistically significant correlation was found (see Table A2 in Appendix) between innovation performance (as reflected by country's innovation performance groups – Innovation Leaders, Innovation Followers, Moderate Innovators - as conveyed by the 2014 Innovation Union Scoreboard or by the size of investment in R&D (R&D intensity) over the whole period of analysis). Indeed, countries presenting higher R&D intensity (e.g., Denmark or Austria, with R&D in GDP well above 2%) evidence, between 2003 and 2008, quite low and decreasing shares of basic R&D in total R&D.

Concerning the period after the crisis, 2009-2012 (cf. Figure 17), no association can be established between the variation of the ration basic R&D in total R&D and the average growth rate of real GDP per capita (the estimate of Pearson correlation coefficient is low and statistically insignificant). But interestingly, those countries with the highest average basic R&D ratios are the ones presenting higher economic performances, that is, higher average growth rates of real GDP per capita (see Table A2 in Appendix – positive and significant correlation between 2009-2012 GDP pc average growth rate and basic R&D ration (average value).

During this period many countries have decreased their share of basic R&D in total R&D, evidencing, on average, much smaller economic performances.

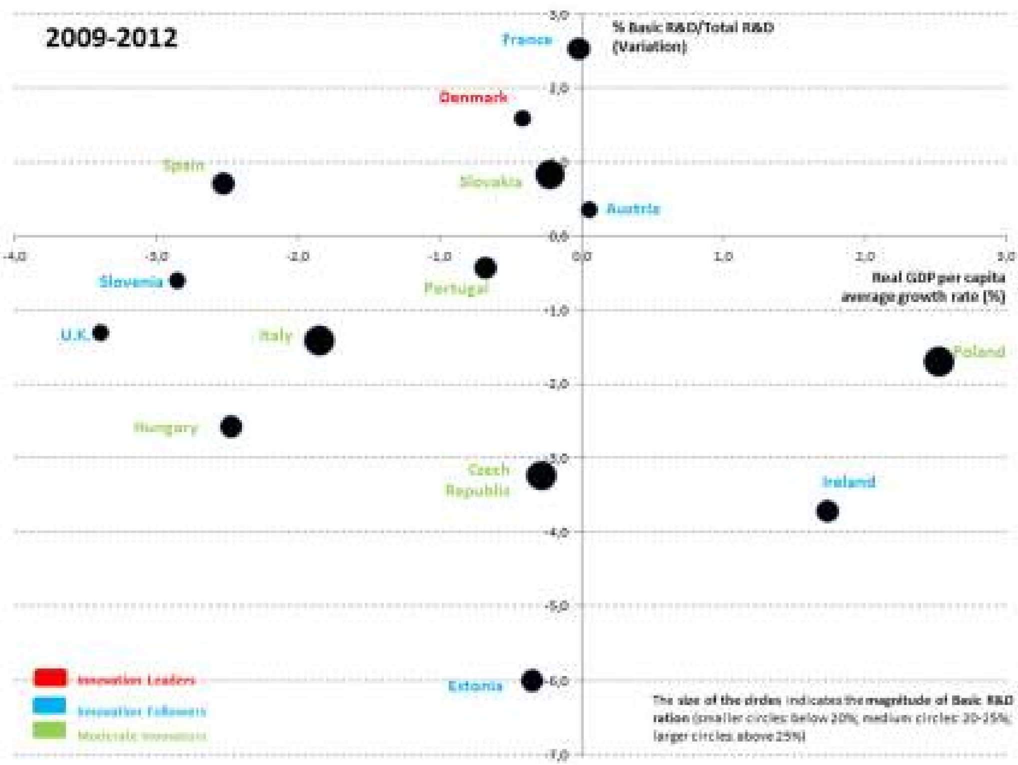

Figure 17: Relation between the variation of the Basic R&D in total R&D ration (%) and the Real GDP per capita annual average growth rate (%), 2009-2012

Note: In the case of Austria and Ireland the period considered was 2009-2011.

Analyzing the overall period in analysis (2003-2012), Figure 18 seems to depict a positive (although not statistically significant) correlation/association (see Table A2 in Appendix) between the variation of the ration of basic R&D in total R&D and the average growth rate of real GDP per capita. If we exclude the cases of Poland and Estonia, data evidence a strong and positive association between basic R&D ration and economic performance although not so much with innovation performance. This latter aspect is likely to be explained by the considerable time lag that exists between variation in basic R&D ration and concrete innovation outcomes.

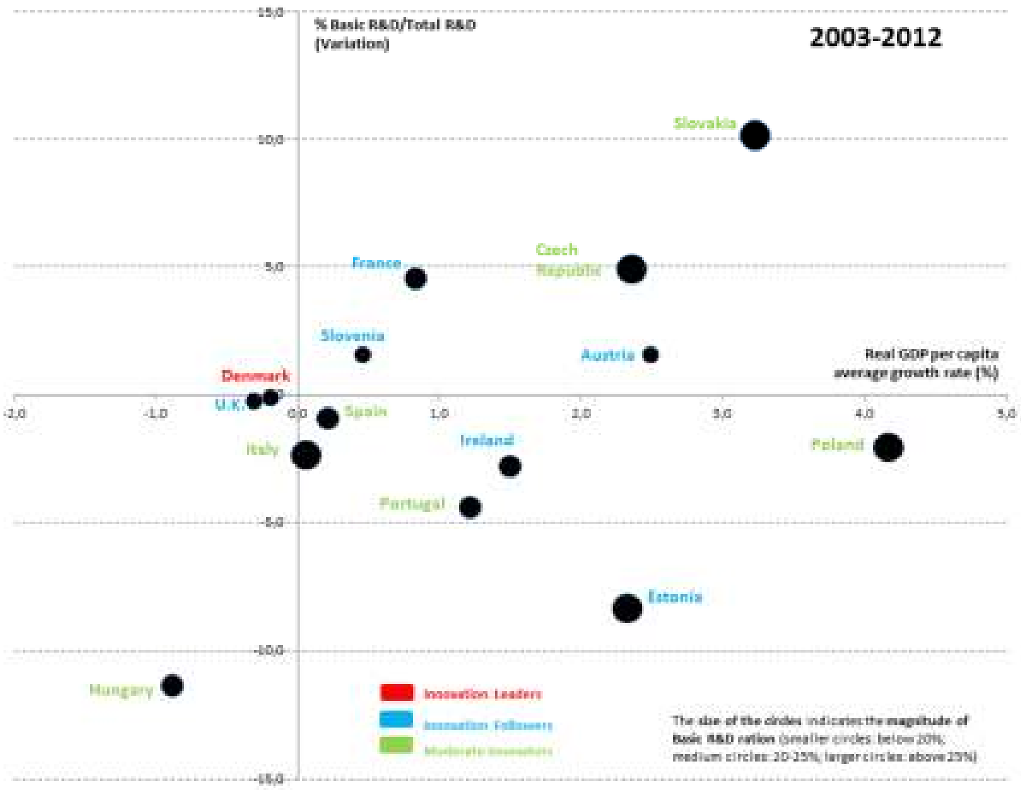

Figure 18: Relation between the variation of the Basic R&D in total R&D ration (%) and the Real GDP per capita annual average growth rate (%), 2003-2012

Note: In the case of Austria the period considered was 2002-2011; for Ireland the period considered was 2003-2011; and for Estonia the period considered was 2005-2012.

5. Conclusion

5.1. Main contributions of the study

The principal aim of this work was to explore, identify and measure the relation between basic R&D weight and the business cycle. Specifically, we aimed at assess the extent to which the recent economic and financial crisis at the level of the European Union produced changes in the relative importance of basic R&D.

A first exploratory analysis based on each country's analysis showed that the groups of countries that present the highest innovation performance according to the 2014 European Innovation Scoreboard (Leaders and Followers) were associated with increased basic R&D ratios. For moderate innovators group, characterized by lower levels of innovation performance, the basic R&D ratios evidenced a declining trend. Such an outcome suggests that the observed reduction of basic R&D shares might endanger catching up processes by moderate innovators and thus contribute to widening their distance to the technological frontier.

Our second main analysis, considering the overall averages in each period, before crisis (2003-2008), after crisis (2009-2012) and the overall period (2003-2012), evidence in general a positive relation between basic R&D ratios variation and real average GDP per capita economic growth, but the relation between basic R&D ratios variation and innovation performance was somehow burled and weak.

5.2. Policy implications

Given that we are dealing with correlations, it is important to bear in mind that causality analysis performed can be in both directions: real GDP per capita growth → variation in the ratio of basic R&D or variation in the ratio of basic R&D → real GDP per capita growth (economic performance).

Thus, increases in the relative weight of basic R&D by better performing countries in economic terms might reflect these latter countries' strategic, longer term, vision, to invest in activities that are likely to produce major breakthrough, radical innovation, and thus sustainable and stronger future economic performance.

The fact that the vast majority of moderate innovators (lower innovation performance countries) observed a decline in their basic R&D ratios and higher innovator performers observed the opposite trend underline the need for governments, especially those facing public budgets constraints, to be cautious with blind and straightforward cuts in all public expenditures. Drastic cuts at the level of basic R&D might endanger countries' future innovation prospects and sustainable growth.

5.3. Limitations of the study and prospects for future research

The data used for this work have some limitations.

The first one, derived from data unavailability which prevent us to analyze the full scope of innovation performance groups – we could not analyze the modest innovator group and in the leader group, data was only available for Denmark.

Additionally, the analysis is only based in exploratory statistical analysis. We could not assess the direction of the causality between basic R&D variation and the business cycle. However, more complex techniques (e.g. cointegration estimations) would require a larger number of observations/countries and over a larger time span.

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Appendix

Table A 1: Estimates of Pearson correlation coefficients

Innovation group	Country	Correlations between GDP pc growth and R&D intensity			Correlations between GDP pc growth and Basic R&D/total R&D		
		2003-2008	**2009-2012**	**2003-2012**	**2003-2008**	**2009-2012**	**2003-2012**
Innovation Leaders	Denmark (DK)	-0.296	-0.933	-0.237	-0.616	+0.890	-0.119
	Finland (FI)						
	Germany (DE)						
	Sweden (SE)						
Innovation Followers	Austria (AT)	+0.102	+1.000	-0.538	-0.811	+1.000	-0.738
	Belgium (BE)						
	Cyprus (CY)						
	Estonia (EE)	-0.721	+0.802	-0.107	+0.406	-0.711	-0.029
	France (FR)	-0.874	-0.915	-0.569	-0.047	-0.943	-0.479
	Ireland (IE)*	+0.774	+0.689	-0.243	-0.381	-0.654	-0.323
	Luxembourg (LU)						
	Netherlands (NL)						
	Slovenia (SI)	+0.432	+0.681	-0.403	-0.071	-0.965	-0.520
	United Kingdom (UK)	-0.801	-0.963	-0.827	-1.000	-0.735	-0.654
Moderate Innovators	Croatia (HR)						
	Czech Republic (CZ)	-0.133	-0.158	-0.435	-0.322	-0.432	-0.342
	Greece (EL)						
	Hungary (HU)	+0.400	-0.432	-0.412	-0.157	+0.340	+0.220
	Italy (IT)	+0.337	-0.669	-0.456	+0.486	-0.651	+0.465
	Lithuania (LT)						
	Malta (MT)						
	Poland (PL)	-0.318	-0.464	-0.570	-0.501	+0.515	+0.002
	Portugal (PT)	-0.021	+0.739	-0.365	-0.155	+0.856	+0.117
	Slovakia (SK)	-0.891	+0.205	-0.487	+0.780	-0.265	+0.243
	Spain (ES)	+0.028	-0.672	-0.509	-0.703	+0.824	-0.735
Modest Innovators	Bulgaria (BG)						
	Latvia (LV)						
	Romania (RO)						

Note: blank cells means that data for these countries was not available. *the periods considered were 2003-2007 and 2008-2011.

Table A 2: Correlations between the relevant variables in the relevant periods (14 countries)

		GDPpc_average_growth_2003_2008	Var_BasicRD_Total_2003_2008	GDPpc_average_growth_2009_2012	Var_BasicRD_Total_2009_2012	GDPpc_average_growth_2003_2012	Var_BasicRD_Total_2003_2012	Innovation_performance	P_BasicRD_average_2003_2012	RD_intensity_average_2003_2012
GDPpc_average_growth_2003_2008	Pearson Correlation	1	0.481	0.420	-0.262	0.901**	0.342	-0.329	0.623	-0.442
	Sig. (2-tailed)		**0.082**	**0.135**	**0.366**	**0.000**	**0.232**	**0.251**	**0.017**	**0.113**
Var_BasicRD_Total_2003_2008	Pearson Correlation		1	0.353	-0.057	0.532	0.750	-0.081	0.397	-0.183
	Sig. (2-tailed)			**0.216**	**0.846**	**0.050**	**0.002**	**0.782**	**0.160**	**0.530**
GDPpc_average_growth_2009_2012	Pearson Correlation			1	-0.128	0.760**	0.130	0.033	0.488	-0.111
	Sig. (2-tailed)				**0.663**	**0.002**	**0.657**	**0.911**	**0.077**	**0.706**
Var_BasicRD_Total_2009_2012	Pearson Correlation				1	-0.186	0.564	0.156	-0.056	0.358
	Sig. (2-tailed)					**0.524**	**0.036**	**0.595**	**0.850**	**0.208**
GDPpc_average_growth_2003_2012	Pearson Correlation					1	0.354	-0.246	0.669	-0.364
	Sig. (2-tailed)						**0.214**	**0.397**	**0.009**	**0.200**
Var_BasicRD_Total_2003_2012	Pearson Correlation						1	0.038	0.325	0.086
	Sig. (2-tailed)							**0.898**	**0.257**	**0.770**
Innovation_performance	Pearson Correlation							1	-0.588	0.860
	Sig. (2-tailed)								**0.027**	**0.000**
P_BasicRD_average_20032012	Pearson Correlation								1	-0.703
	Sig. (2-tailed)									**0.005**
RD_intensity_average_20032012	Pearson Correlation									1
	Sig. (2-tailed)									
c. Listwise N=14										

(dark grey)	Positive significant statistical correlation (at less than 10% significance)
(light grey)	No significant statistical correlation (at less than 10% significance)
(black)	Negative significant statistical correlation (at less than 10% significance)