A GLIMPSE INTO THE R&D PERFORMANCE AT EUROPEAN UNION LEVEL

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Abstract: *The persistent uncertainty after the global economic crisis together with EU diffuse perspective challenges the possibilities of boosting regional and global economic growth. The confidence in EU as an innovation-driven regional economy has to be renewed: the base points of economic life must be restored, fresh educational approaches are needed and the competences, that are a precondition for success, must be brought back or reconstruct. Thus, research and development (R&D) public and private policies must play a key role in efforts to create wellbeing and sustainable growth at EU member countries. A large number of studies have been conducted in order to evaluate (directly or/and indirectly) the performance of R&D on society but there is still a lack of broadly acceptable and rigorous applicable methodologies for R&D performance assessments. In this sense, on the grounds of some Eurostat and OECD indicators, the expected results of this article are intended to contribute to a better understanding of the R&D performance on overall EU economy and on some EU member countries.*
Keywords: *R&D; quantification, R&D performance, innovation.*
JEL Classification: *O32, O40, O52.*

1. Introduction

Usually, the research and development (R&D) plays an important role in the development of technologies, the society and the economy as a whole. In the context of the regaining the momentum over the crisis, the R&D is an important starting point for development of new skills, education, public accountability, knowledge, methods, processes and products. An impressive number of research papers have been conducted in order to evaluate the performance of R&D on economic growth, on educational system, but also on society. Still, there is room for improvement regarding the assessments of methodologies for R&D performance.

The R&D data and situation can be evaluated on the grounds of its performance or impact:

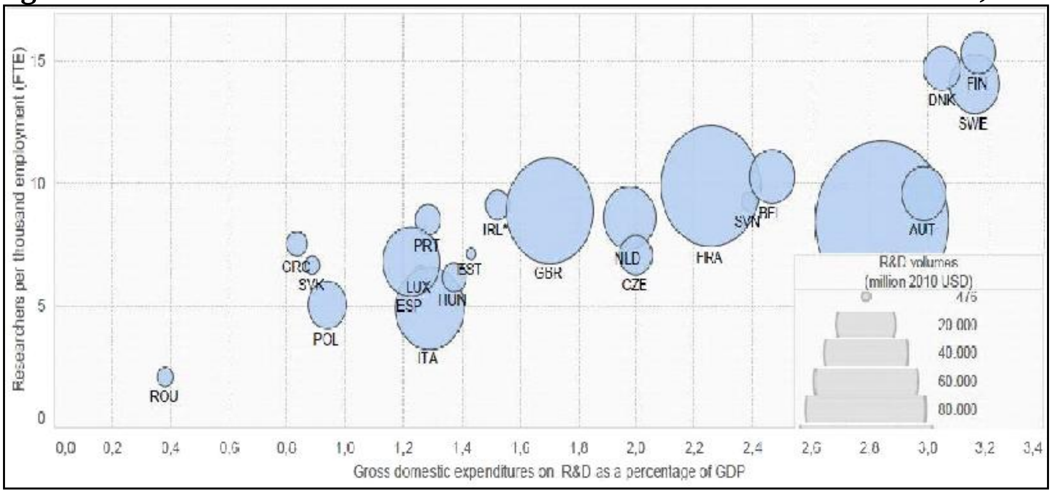
- Over the economy, environment, social, cultural, technology and science, etc. (on the overall or on specific area).
- On micro or macro level (firm or systemic level).
- On private or public area.
- On the present time or ex-post.
- On a single country or on extended region or even the world, etc.

Also, the R&D can be analysed through the direct or indirect impact, being a tool of strategic planning or rather more a “curiosity-oriented” (Salter and Martin, 2001). The importance of basic research and the one oriented more on “curiosity” suggest that the need for general advancement of knowledge is quite significant. According to OECD data, when we refer to European Union (EU) countries we can notice that the “general advancement of knowledge” is the most important field when concerning the allocation gross domestic expenditure at least in higher education. For example, in Denmark and Romania, taking into account the socio-economic objective, the “general advancement of knowledge” is well targeted also at the government level and when we look at Spain the “industrial production and technology” is well targeted at business enterprise level, while the government and private non-profit organisations are most concern of research in health domain.

At the same time, looking at OECD data, we can notice that at EU level the “experimental” research is the most important, followed closely, and with a growing percentage, by “applied” research. The “basic” research grew also according to OECD data, since 2010, but still is a small part (less than a half) of “experimental” research.

The importance of research in the public and private policies of a country can be depicted by the evolution of gross domestic expenditure as percentage of GDP and the number of researchers per thousand of people in employment. According to OECD data, taking into account these indicators, there is no surprise that the Nordic countries of EU like Finland, Denmark and Sweden are at the top, while countries from Southern and Eastern flank of EU are lagging behind (e.g. Romania) (see Figure no.1.).

Figure no.1. Human and financial resources devoted to R&D at EU level, 2014



Source: OECD data

According to OECD data, note mention that, at the level of the year 2014, in the EU the most significant share of researchers worked in business enterprises, followed by higher education field, a small percentage worked in government and an insignificant share in private non-profit organisations.

The rationale of the paper can be more clear emphasised by the need (on medium term) not only for sustainable growth of the EU economy, but mostly, on short term, for the need of reinventing the “old world” (Europe) through innovation, competitiveness and economic performance. Although research and development is only a starting point in achieving the objectives mentioned above, however, its importance reclaims the increasingly higher and higher position in the architecture of smart public and private investments. Therefore, the article aims to point out the importance of the performance analysis or the impact of R&D investments on innovation and the prosperity per capita, in order to motivate the increase of R&D investments. It should be noted that, regardless of relevance the impact analysis, for durable results, the investments in R&D should be done on a medium and long time horizon, should provide continuity, and should be significant in certain areas of concern for the economy and sometimes should disregard the apparent lack of impact on the short term. Moreover, the public investment should not take a very well defined direction towards the applicative area, but should encourage the "escape" of knowledge from the public research and the blend of knowledge and information between public and private domains.

2. Literature review

The technological breakthroughs, the research and innovation processes were developed in many cases as a result of the needs from economy and institutions (Rosenberg and Birdzell, 1990). The public sector of R&D has a big importance in the competitiveness of a region of the world and of a country, but as Tijssen (2002) mentioned there is still a need for trusty data, analytical tools and comprehensive models for the understanding of the relationship between R&D and industrial innovation. He points out that about 20% of the innovations of the private sector are based more or less on research on public sector. Also, he outlines that the citations regarding the research literature concerning the patents does not highlights so well the link between research/science and technology. In papers of Arrow (1962), there are mentioned the informational features of scientific knowledge. This implies that the public funded research is freely available to all companies, and the private funded research could be available to others companies beside the producers (non-excludable feature) (the idea sustained also by Cohen and Levinthal, 1989, in the sense of assimilation of the external knowledge) and the access to knowledge of other companies cannot reduce the knowledge of the one which produce it (non-rival feature). So in Arrow's view the scientific knowledge is a public good (contrary to Callon's opinion) and the research at the private companies' level cannot be assumed and disclosed because the companies cannot understand and use all the benefits of the research.

At the same time, the impact of knowledge and the stock of knowledge noticed a significant gap in time until the materialisation in results. Thus, Adams (1990) found that between scientific publications and the productivity and/or economic growth could be a period of 20-30 years of delay. Also, in Mansfield study (1998) it is mentioned that the academic papers were becoming more and more important for various industries and that the delay in time between academic research and their implementation in practice has been reduced (on the grounds of the more applied work of universities).

If the private research has a more short-term or a more applied orientation (towards an individual firm or sector), under the increasing pressure to justify the public expenditure on basic research the governments and international organisations have conducted there own studies in order to prove the importance of public research (e.g. Bilbao-Osorio, 2008). Conformable to Salter and Martin (2001), they found in their review that the public funding of basic research has considerable economic benefits and that these benefits are heterogeneous, difficult to measure and track, mostly indirect and usually very subtle. According to the above authors, the main contributions of public research are in the growing learning capabilities, in expressing new ideas, methods and opportunities and also in "trained problem solvers".

In conclusion it is more than evident that it is impossible to measure accurately the extent to which a domain or the whole economy gains social and economic benefits from public and private research, but is evident that the direct and indirect impact of research have a saying in the evolution of technology, productivity and economic growth.

3. Methodology

At EU level, in the evaluation of the R&D performance, it is hard to trace the research influence over the specific outcome indicators and even over the economy as a whole. Having a serious lack of data availability it is difficult to use any econometric method. Still, I tried to cope with this situation, applying an initial analysis on several indicators for all UE 28 countries in order to see possible correlations between them in two distinct times (2008, the year when the international crisis burst and 2015, the last year with available data), then using an analysis of a more discreet nature it has been used a time series for the period 2004-2014. Thus, despite the fact that it offers a very limited picture of reality, the present article uses the case study approach at the EU28 level as a whole and at the level of a few important countries selected (Denmark, Spain and Romania). The selection of countries was made according to the data availability and especially in order to capture three different types of countries: countries without a clear R&D strategy and without a relevant investment in R&D (e.g. Romania), countries with a not very ambitious strategy but with a relatively average investment in R&D (e.g. Spain) and countries with an ambitious R&D policy and with a relevant R&D investment (e.g. Denmark). These three typologies capture also the regional differences of Europe (East – South – North), but also a development seen as an evolution over time of three types of economies (transition to developed countries – medium developed countries – developed countries). Thus, burning steps or catching up process would involve that the least developed countries to invest heavily in research and development (e.g. Romania).The data used in this paper were collected from Eurostat (for correlations analysis) and OECD (for mare general conclusions). As any case study the present paper acknowledges its limitations, being very specific to a certain context and certain time and being unable to be extrapolated to other experiences; however, the results worth consideration.

4. Results

In order to apply an econometric analysis, first it has been taken into consideration all 28 countries of European Union, in two different moments 2008 and 2015. The selected indicators were: Gross domestic expenditure on R&D (GERD), Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), Patent applications to the European patent office (EPO) by priority year (number of patents), Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010). In table no.1 and table no.2 it can be seen that no important correlations worth mentioning with the exception of the one between patent applications to the European patent office (EPO) and the number of total researchers. In 2015, this correlation and a few others grew slightly. Another correlation that could give some thoughts is the one between real GDP per capita (euro on inhabitant) and Gross domestic expenditure on R&D. This correlation in 2015 decreased on the grounds that in crisis times, in some countries of EU28, the spending with research and development stagnated and even reduced, also the real GDP per capita evolution did not increase too much in 2015 compared to the 2008 base year.

Table no. 1. The correlation matrix between a number of indicators of input and output regarding the R&D in 2008 at EU28 level

	GERD(%PIB)	*TRE(FTE)*	*PA(EPO)*	*RGDPCap*
GERD (%PIB)	1.00			
TRE(FTE)	0.35	1.00		
PA(EPO)	0.40	0.86	1.00	
RGDPCap	0.61	0.17	0.21	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR (FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).

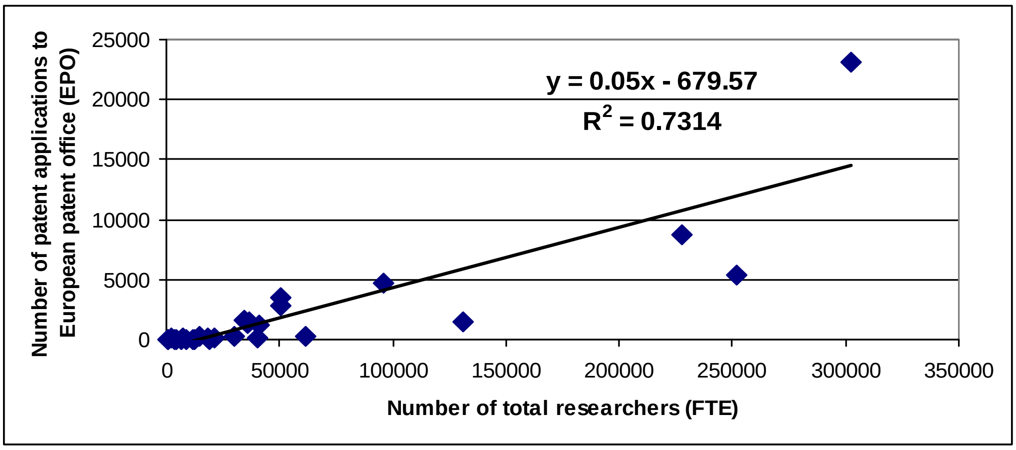
Table no. 2. The correlation matrix between a number of indicators of input and output regarding the R&D in 2015 at EU28 level

	GERD (%PIB)	*TRE(FTE)*	*PA(EPO)*	*RGDPCap*
GERD(%PIB)	1.00			
TRE(FTE)	0.36	1.00		
PA(EPO)	0.46	0.89	1.00	
RGDPCap	0.51	0.18	0.23	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR (FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).

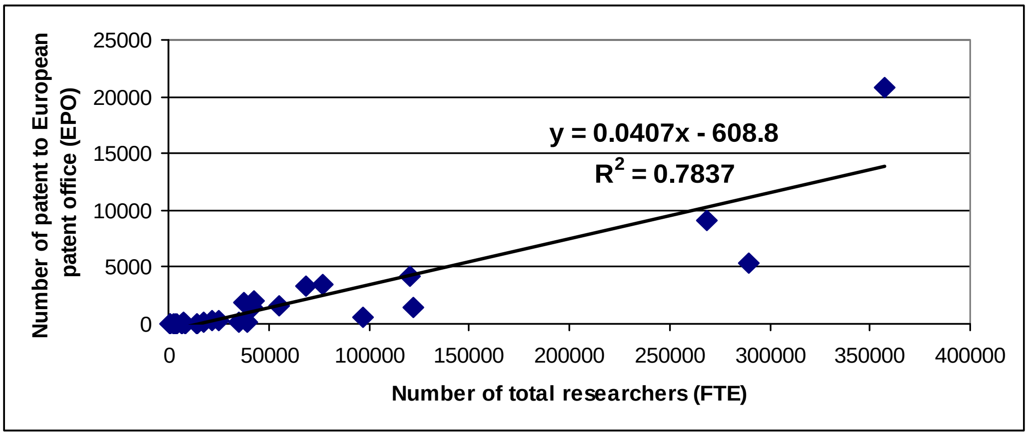
When considering a scatter analysis, the relation between patent applications to EPO and the number of total researchers is quite well illustrated by the regression function, which demonstrated that the R square improved to 0.78 in 2015, being a very good fit. Also, the results are quite reliable because the Significance F was less than 0.05 both in 2008 and 2015 (e.g. in 2015 it was 3.92849E-10).

Figure no. 2. The number of patent applications to European Patent Office and the number of researchers on the basis of full-time equivalent at EU28 level in 2008



Source: Eurostat data, author's processing

Figure no. 3. The number of patent applications to European Patent Office and the number of researchers on the basis of full-time equivalent at EU28 level in 2015



Source: Eurostat data, author's processing

Another interesting analysis it has been undertaken over time (the 2004 – 2014 period) with the same indicators for the EU-28 countries (overall average), Denmark, Romania and Spain. The results deserve to be presented and discussed from multiple perspectives.

First, for EU28, it can be seen that the relations between patent application to EPO and GERD spending as % of GDP and between patent application to EPO and the number of researcher are negative and very small. This fact suggests that despite an increase in research financing and research employment, the activity of the patent application is roughly unchanged al EU28 level on the period of 2004-2014.

Table no. 3. The correlation matrix between a number of indicators of input and output regarding the R&D for the period 2004-2014 for EU28

	GERD (%PIB)	***TR(FTE)***	***PA (EPO)***	***RGDPCap***
GERD (%PIB)	1.00			
TR(FTE)	0.97	1.00		
PA (EPO)	-0.26	-0.09	1.00	
RGDPCap	0.36	0.54	0.56	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR(FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).

The strong correlation between GERD and the total number of researchers is not a surprise, being mostly a natural factor in the condition of increasing constantly the GERD spending. Also, is not surprising that real GDP per capita is positively and increasingly correlated with GERD (%PIB), with the number of researchers and with the patent applications.

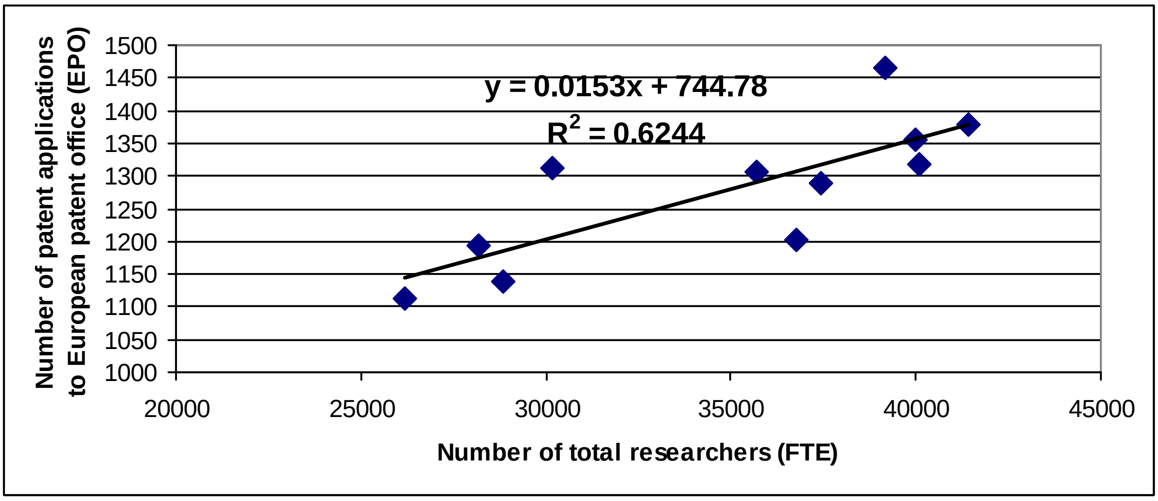
When looking at Denmark, the correlations are vice versa than at the EU level, the relations between patent application to EPO and GERD spending as % of GDP and between patent application to EPO and the number of researcher are positive and strong.

Table no. 4. The correlation matrix between a number of indicators of input and output regarding the R&D for the period 2004-2014 for Denmark

	GERD(%PIB)	*TR(FTE)*	*PA (EPO)*	*RGDPCap*
GERD (%PIB)	1.00			
TR (FTE)	0.96	1.00		
PA (EPO)	0.67	0.79	1.00	
RGDPCap	-0.41	-0.21	0.10	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR (FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).

Figure no. 4. The number of patent applications to European Patent Office and the number of researchers on the basis of full-time equivalent in Denmark, 2004-2014



Source: Eurostat data, author's processing

About Romania, the correlation matrix looks disturbing, except the relationship between real GDP per capita and patent applications and between real GDP per capita and GERD, though the last correlation is relatively small (see Table no.5.)

Table no. 5. The correlation matrix between a number of indicators of input and output regarding the R&D for the period 2004-2014 for Romania

	GERD (%PIB)	*TR(FTE)*	*PA (EPO)*	*RGDPCap*
GERD (%PIB)	1.00			
TR(FTE)	-0.32	1.00		
PA (EPO)	-0.31	-0.55	1.00	
RGDPCap	0.32	-0.72	0.69	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR(FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP *per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).*

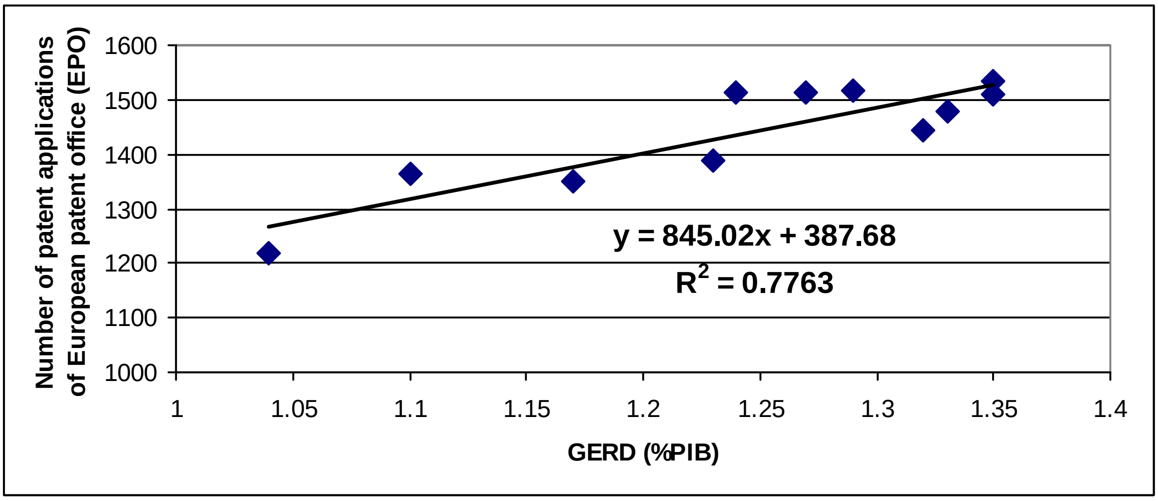
When we take into account Spain, the patent applications have important correlations with GERD (%PIB) and with total number of researchers.

Table no. 6. The correlation matrix between a number of indicators of input and output regarding the R&D for the period 2004-2014 for Spain

	GERD (%PIB)	*TR(FTE)*	*PA (EPO)*	*RGDPCap*
GERD (%PIB)	1.00			
TR(FTE)	0.99	1.00		
PA (EPO)	0.88	0.87	1.00	
RGDPCap	-0.12	-0.04	-0.44	1.00

Source: Eurostat data, author's calculations, notations: GERD (%PIB) - Gross domestic expenditure on R&D; TR(FTE) - Total researchers (FTE), by sectors of performance (notation: FTE - full-time equivalent), PA(EPO) - Patent applications to the European patent office (EPO) by priority year (number of patents), RGDPCap - Real GDP per capita (growth rate and totals, percentage change on previous year, EUR per inhabitant, chain linked volumes 2010).

Figure no. 5. The number of patent applications to European Patent Office and GERD (%GDP) in Spain, 2004-2014



Source: Eurostat data, author's processing

Considering a scatter analysis regarding Spain, the relation between patent applications to EPO and GERD is quite well illustrated by the regression function, which demonstrated that the R square of 0.78 is a good fit.

5. Conclusions

Usually the need for research and development (R&D) is more than recognized at the internationally, regional (especially at EU level) and national level. The R&D activities cover the creative work and envisage the need for increasing the knowledge stock. The R&D activities comprise experimental, applied and basic research. The experimental research is a systemic work, drawing its backgrounds on basic and practical research, in order to conceive and produce new products and materials and/or to improve the systems and processes in place. Concerning the OECD data, we can notice that at EU28 countries level the "experimental" research is the most important, followed closely, and with a growing percentage, by "applied" research. The "basic" research grew also according to OECD data, since 2010 until present, but still is less than a half of "experimental" research level.

According to OECD data, when we refer to European Union (EU) countries, taking into account the socio-economic objective, we can notice that the "general advancement of knowledge" is the most important field when concerning the allocation gross domestic expenditure at least in higher education. If we look at Denmark and Romania, the "general advancement of knowledge" is also well targeted at the government level. A more practical approach can be seen when we look at Spain because the R&D gross domestic expenditure focuses on the "industrial production and technology". In Spain the "industrial production and technology" is well targeted at business enterprise level, while the government and private non-profit organisations are most concern of research in health.

At EU level, in the evaluation of the R&D performance, it is hard to trace the research influence over the specific outcome indicators and even over the economy as a whole. Despite of the lack of data availability, using Eurostat database, I applied two sets of analyses: an initial analysis, on several indicators for all UE 28 countries, in order to see possible correlations between them in two distinct times 2008 and 2015, and a second one, using a time series for the period 2004-2014 for EU28 average and for a few countries like Denmark, Spain and Romania. The selected indicators were: Gross domestic expenditure on R&D (GERD), Total researchers (FTE), Patent applications to the European patent office - PA (EPO) and Real GDP per capita. Concerning the first analysis, it can be seen that no important correlations worth mentioning, excepting the one between patent applications to the European patent office (EPO) and the number of total researchers (e.g. in 2015 was 0.89). The assertion of the above is based on the fact that on the two points in time (2008 and 2015) can be seen that the relationship between Real GDP per capita and GERD weakened in 2015 compared to 2008, while the relationship between PA (EPO) and GERD increased relatively modest. This suggests that the investment in research and development at the level of EU28 countries, despite its modest growth in the period 2008-2015, is not an infallible cure to the collapse or to the economic downturn of EU28 countries.

The second analysis procedure is performed in time (the 2004 – 2014 period), with the same indicators for the EU-28 countries (overall average), Denmark, Romania and Spain. The results for EU28 show that there is a strong positive correlation between GERD (%GDP) and total number of researchers and a less intense positive correlation between real GDP per capita and patent applications. When looking at Denmark, the correlations are vice versa than at the EU level. Thus, the relations between patent application and GERD spending (% of GDP) and between patent application and the number of researcher are positive and strong. Looking at Romania, note mentioning that the correlation between real GDP per capita and patent applications in quite well. Tacking into account Spain, the patent applications have important correlations with GERD (%PIB) and with total number of researchers. The conclusions point out to a rather indirect impact of R&D on the economy, taking into consideration also the delay in time mentioned also by literature.

Considering the lack of data and other methodological problems, we are in Tijssen (2002) assent, which pointed out that there is still a need for trusty data, analytical tools and comprehensive models for the understanding of the relationship between R&D and industrial innovation and between R&D and the economic growth, in general.

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