RT. A Journal on Research Policy & Evaluation 2 (2015)
Submitted on 18 May 2015, revised on 18 August 2015, accepted on 22 September 2015, published on 12 October 2015

Doi: 10.13130/ 2282-5389/4816

Science Policy for an increasingly diverging Europe

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Abstract: This paper argues about the need for a revisited public policy framework giving priority to knowledge and technological change across the entire Europe, by discussing new cumulative data on R&D expenditure and the qualification of human resources across Europe. It takes a wide international comparison after a decade hit by recession and economic and budgetary problems, which shows an increasing internal divergence on knowledge investments across Europe, beyond the increasing gap between Europe as a whole and North America. As a result, the paper argues that new paradigms and conditions for responsible science and innovation policy across EU require the collective action of R&D institutions and a system approach to higher education, together with new initiatives towards international cooperation across an enlarged Europe.

Analysis shows that chronic backwardness in science and technology in many European peripheries, including in EU southern and eastern regions, have been significantly overcome over the last decade. Nevertheless, their growing scientific and technological capacity is now associated with an increasing vulnerability as a result of the growing international competition for qualified human resources. Additionally, the comparative analysis of levels of economic diversification and sophistication across Europe, suggests the need to insist on qualification and institutional strengthening. This should consider active public policies to attract and retain qualified human resources all over Europe, as well as considering public actions towards promoting new markets. The way in which the economic fabric may gain competitiveness and access to external markets may require enhancing the degree of internationalization of the scientific community and encouraging international knowledge and innovation networks.

1. Introduction: an increasingly diverging Europe

In a decade hit by recession and economic and budgetary problems, which public policies for science, technology and education are necessary in the near future, both for individual member states as well as the EU as a whole?

This question is relevant because it has become a common place to argue that science and technology permeates everyday life, but a new debate is emerging about the related role of the State, with emphasis in Europe (Mazzucato, 2013). The continuous need for

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growing investments in formal knowledge activities by countries and firms (Aghion, et al., 2009), underlines the search for competitive advantages and the establishment of sustainable bases for further development of the required "smart specialization" for Europe (Foray, 2009; 2015). This trend often combines mixed patterns of competition and collaboration (Bengtsson and Kock, 2000) and, in the specific case of Europe, is growingly intertwined to face a fast-paced, globalized and uncertain world (e.g., Owen et al., 2012; Stilgoe, et al., 2013).

The economic situation over last years has had major implications on emerging policy discussions throughout Europe on whether or not to cut future investments in the realms of science and (higher) education (e.g., Heitor at al., 2014). This question has driven the creation of "step4EU – Science, Technology, Education and Policy for Europe" (http://www.step4eu.org/), a European wide network aimed to foster the systematic observation of issues in science and technology, higher education and public policy in Europe based on in-depth research. The debate has been strengthened as a result of the deep international crisis that affected Europe (e.g., Mazzucato, 2013) and to which many analysts, scientists and scientific organizations have turned their attention, in several European regions, with special emphasis on southern European countries.

Undoubtedly there was progress in science, technology and higher education throughout Europe, but as a whole, Europe has met neither its goals nor its promises in this area (EC, 2014). It is under this context that the research hypothesis driven this paper is that the new paradigms and conditions for science and innovation policy across EU require the collective action of R&D institutions and a system approach to higher education, together with new forms of international cooperation.

The challenges for Europe are immense, independently if they are global, national or local in nature, as most are to all effects transversal (e.g., global warming). An adequate policy framework not only helps mediating the interface between science, education and society, but also contributes to shaping systems, strategies and development patterns (Stilgoe, et al., 2013). Ultimately, the question is how to avoid the surprising estimates of UNESCO (2012), that warns about the possibility to have a "lost generation" of 200 million young people – the bulk of which are expected to possess some kind of higher education qualification.

In addition, for Europe to meet the challenges of the Rome Declaration, signed in November 2014 by European Ministers responsible for science, inviting all the higher education and research institutions across Europe to incorporate Responsible Research and Innovation (RRI) as a key scientific attitude, there is the need of an adequate policy framework at EU and national levels. Although the idea of "responsible science" seems relatively consensual, it raises new theoretical questions about the growing trend in recent decades to enhance the economic appropriation of the scientific activity (Owen et al., 2012). It also questions the freedom of learning and research, as well as the "political appropriation" of science and, above all, requires deepening current knowledge on the "pathways of excellence" in scientific and higher education activities (Stilgoe, 2014).

These issues, among many others that could have been listed, recall similar debates in the eighties, as associated with overcrowding among students, lack of resources, increased costs of the school places, maladjustment between the educational and productive systems and the slow speed of response to labor market demands in the educational response (Coombs, 1985). In that occasion, it was clear that investments in education were important drivers of economic and social development (Gilead, 2012). Indeed, investing in education in Europe, and elsewhere, contributed to develop new capacities and skills, together with professional competencies that mitigated negative effects of cyclic crisis. The flexibility in addressing economic and societal dynamics has been facilitated and stimulated through science and education (e.g., Robertson, 2005;

Selwyn and Brown, 2000), although many authors have argued that in the absence of a coherent policy framework (including collaborative arrangements, quality assurance procedures and other feedback mechanisms, among other issues) science and education are necessary conditions but not sufficient for wealth generation. In addition, analysis has also shown that budgetary cuts in science and (higher) education over time have exacerbated economic inequality and social exclusion (OECD, 2012).

In this context, scientific and higher education institutions are critical agents given their privileged locus of repositories of knowledge, skills and competencies, as well as their effective contributions to the economy. Thus, the current economic situation presents a strategic opportunity for revisiting the role and mission of advanced training, knowledge and innovation in times of post-financial crisis in Europe. This requires an adequate and systematic observation of policies and budgets across Europe in a way to report, publicly and periodically, relevant information and early warnings on the state of policies and budgets in each country and at EU level.

This paper follows previous studies (Heitor et al, 2014; Heitor 2015), which address four priority aspects: first, the paths for a new industrialization pattern that is required in order to encourage socioeconomic resilience approaches (e.g., McKinsey Global Institute, 2012); second, the need to insist on persistent and informed investment policies in science and technology, sustained in demanding ways of promoting scientific and technological culture in society, and the social appropriation of knowledge; third, the need to strengthen qualification and learning, in a context of further democratizing the access to knowledge and innovation, which calls for openness of higher education and the preservation of the social function of higher education graduates (Heitor and Horta, 2014); and fourth, a new era for the internationalization of higher education in association with active public policies to sustainable and long term cooperative ventures with international partners (Heitor, 2015).

Section two presents a summary of data and figures regarding the evolution of investment in science and technology in Europe over the past decades. Section three provides new sets of data regarding the accumulation of knowledge investment and its relative impact across Europe. Section four discusses the results, putting the evolution of national science policies into perspective. It starts by linking public investment in science and technology to the systematic reinforcement of human capital and includes new data on the impact of S&T policies on the economy in view of the diversification and internationalization of several European countries. The paper concludes with a short discussion of policy implications.

2. Data and Facts: the dynamics of the investment in science and technology

Figure 1 extends the data published a few years ago by UNESCO (2010; for 2002-2007) for the period 2002-2012 and compares the world shares of GDP and of GERD (Gross expenditure in R&D) for the G20 for an entire decade. It is important to note that the most dynamic economies (including USA, Germany and China) keep increasing their gross expenditure in R&D and, above all, are characterized by a world share of GERD higher than their world share of GDP. The most notable figure is that of China, that has increased over the decade under analysis its world share of GERD from 5 to 15%, surpassing its world share of GDP. On the other hand, Europe as a whole decreased the world share of GERD from 30% to 23%, while its world share of GDP decreased from 31% to 22%. For comparison, US keeps a much larger difference between its world share of GERD (32%) and its world share of GDP (19%), which may represent a proxy for the critical importance of investing in knowledge production and diffusion.

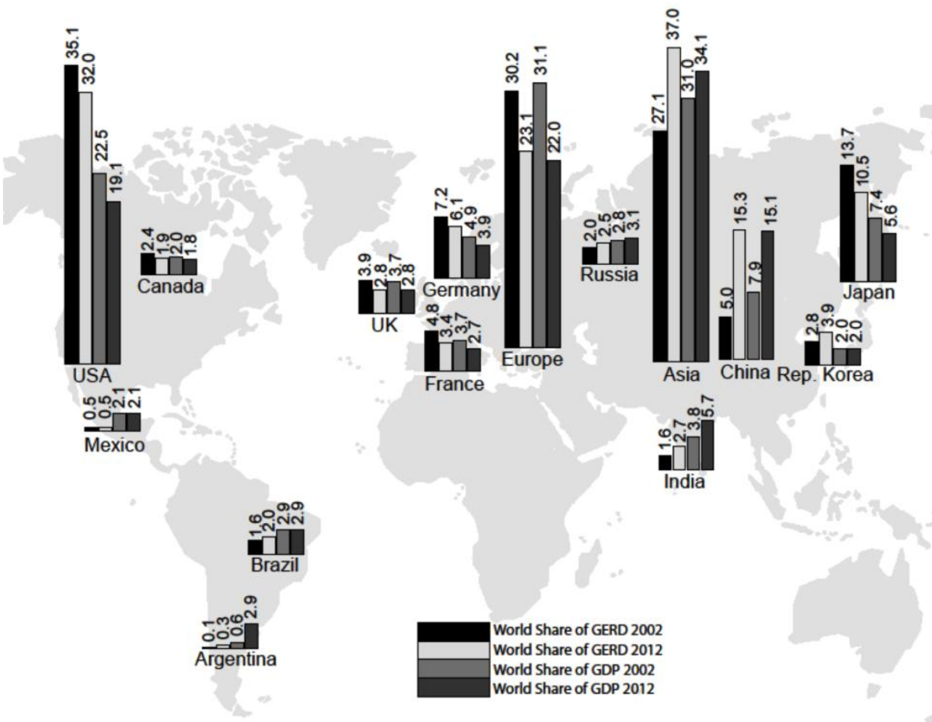


Figure 1. World share of GDP and GERD for the G20 over the last decade (2002-2012); values in %; Note: calculations by the author, adapted by UNESCO (2010).

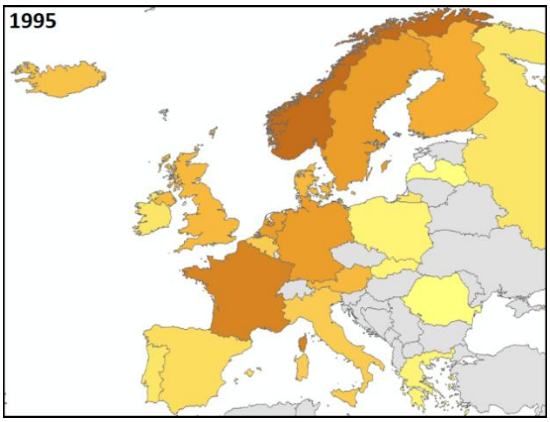
In relation to the relative European competiveness in relation to other parts of the world, Figure 1 also shows the quasi-stagnant levels of R&D investment in Russia and South America, albeit with some noteworthy national initiatives. For example, gross expenditure in R&D in Brazil has not been able to surpass 1.3% of GDP, and in Argentina it is kept as low as 0.6%. Overall, the South America region lags in R&D capacity, with Brazil appearing to have under-performing expectations, with 1.6 fewer publications (in the Science Citation Index) by million inhabitants than Chile, and 5.5 than Germany.

In terms of political action, science policy is undertaken through annual appropriations for Science and Technology (S&T), which are approved each year by national parliaments within the context of state budgets (i.e., “GBOARD - Government Budget Outlays or Appropriations of R&D”, in technical nomenclature). Looking back to what the evolution of the European scenario has been over the last two decades regarding budget appropriations for S&T, Figure 2 shows that, in 1995, France and the northern European countries had the largest appropriation per capita for S&T. By contrast, over the 2000-2009 period, in line with an increase in the German budget allocated to S&T, which grew by 60%, there was a relative stagnation of the French budget after a 12% decrease between 2005 and 2007. During that period (see, for example Gago and Heitor, 2007), some small and medium-sized European countries increased their investment in S&T, particularly Portugal and Ireland (which almost tripled their budget) and Finland and Belgium (about 1.6 times more).

Figure 3 quantifies the detailed evolution of the various national budgets allocated to S&T and the analysis shows that, in 2012, Germany, the Netherlands and mostly northern European countries allocated the largest annual budgets per capita to S&T. The picture that emerges is characterized by an increasingly large divergence at national level within Europe (EC, 2014), mostly after a decrease in all annual budgets between 2009 and 2012, with the notable exception of Germany. In other words, 10 years ago, France and Germany were characterized by similar budgets allocated to Science and Technology (Figure 3 b), whereas today the French budget has been reduced to around 60% of that of Germany. Over the same period, the UK's budget allocated to S&T was reduced by more than 10%, Italy cut its S&T budget by 15%, and Spain by 17%. These cuts at national level are associated with a relatively stagnant overall European budget throughout the decade, despite some important initiatives, including the creation of the "European Research Council" in 2005. This was the result of joint efforts from scientists and their most influential organizations across the continent, as recently discussed by Celis and Gago (2014).

It is important to note that Germany is the only EU country that continued to increase its S&T budget, even in times of crisis. From 2013, Germany's S&T budget has been similar to that of France and the UK taken as a set. By contrast, only Germany and northern European countries have met the European targets for R&D expenditure, which were set at 3% of GDP (EC 2014).

In order to understand the situation in Southern Europe, it is interesting to look at the specific case of Portugal. Its annual budget for S&T only reached 1% of GDP in 2008, despite the expectation that this figure could be achieved in the 1980s (see, for example, Gago, 1990). It was only about 0.5% in 2000 and 0.8% in 2005, accounting for nearly 3% of the overall public budget only by 2011 (Heitor and Bravo, 2010; Heitor et al., 2014). It therefore increased by 33% in relation to GDP between 2005 and 2011 and by 23% in relation to the global State budget. In Europe, only Estonia, Luxembourg and Slovenia grew at a higher rate during that period.



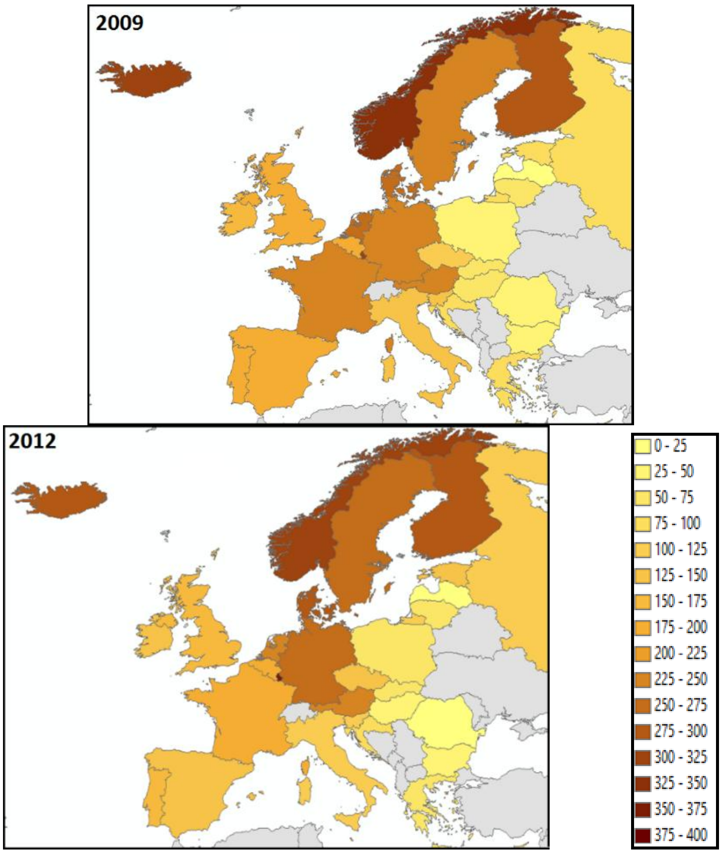
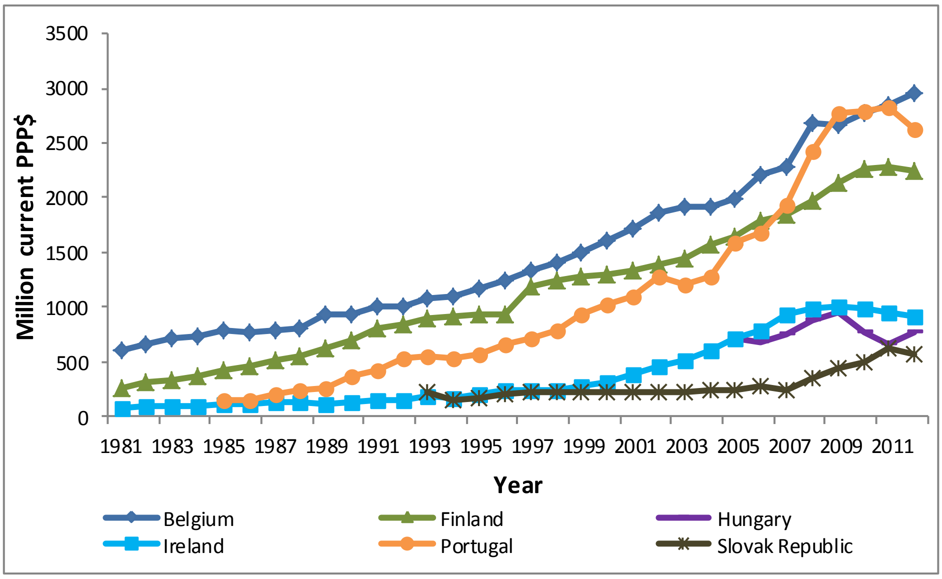
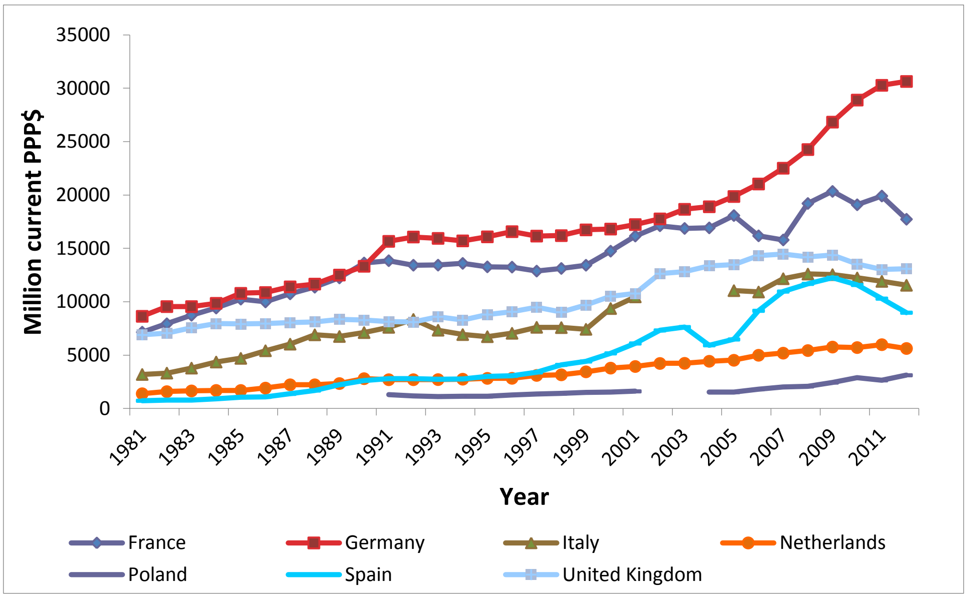


Figure 2 – Evolution of "Government Budget Appropriations or Outlays for R&D"; GBOARD)/capita) in Europe for 1995, 2009 e 2012 (values corrected for "Purchasing Power Standard, PPS", per inhabitant in 2005, at constant prices).
Source: EuroStat.

In Portugal (as well as in Spain, as discussed by Núñez, 2013), however, there has been in recent years a decrease in the budget allocated to S&T, associated with the perception that policies must be changed. In this regard, two types of arguments have been put forward, which are often conflicting to each other and may result from distinct political influences (Gago, 2014). On one hand, there is a recurrent argument in Portugal and Spain for targeting public support to companies and mostly to business competitiveness, and, on the other hand, the need for increasing selectivity criteria of public support based on the claim of overqualified personnel. This has resulted, for example, in the reduction of the share allocated to advanced education (i.e., reduction of doctoral and post-doctoral scholarships funded by the Portuguese Foundation for Science and Technology, FCT) and scientific employment (i.e., ending a large majority of PhD researcher contracts, directly supported by FCT).



a) Sample of small and medium EU Countries.



b) Sample of large EU Countries (Netherlands is included because of the size of the budget).

Figure 3 – Government Budget Appropriations or Outlays for R&D (GBOARD), 1981-2012.
Source: OECD.

As a result of these policies, the level of support for attracting young researchers from abroad to work in Portugal (and Spain and Italy, among other countries) has been considerably reduced. Besides, the brain-gain effect, which had finally took place in 2009 after so many decades of outflows of talents, has probably faded away (i.e., brain-drain, as discussed in detail by Heitor et al., 2014). The argument of overqualified personnel and the related reduction of the level of support for advanced education have re-emerged the debate on the sustainability of doctoral and post-doctoral studies in Portugal, in a context of growing international competition for qualified human resources (OECD, 2012; Stilgoe et al., 2014; Heitor et al, 2015).

Despite the lack of accurate data on the migration qualification structure, Figure 4 shows the substantial growth of migratory flows from Southern to Northern Europe since 2010, mostly of qualified young people (OEm, 2014). The respective impact on the reduction of the scientific and technological capacity in Southern European countries and regions is not dully quantified or described, but has been recurrently debated by the scientific and academic community.

Still regarding Portugal, one of OECD's last reports regarding the status of science and technology at international level, OECD (2012), identifies three fundamental aspects that characterize the development of the country's scientific and technological capacity in recent decades. First, the OECD recognizes the Portuguese progress in scientific output, with publications in the top-quartile journals per GDP, similar to OECD average. Second, industry-financed public R&D expenditure per GDP and businesses in particular, remains well below OECD average. Third, the base of tertiary education of working population, considered as a whole, is still considerably below OECD's average levels (i.e., "adult population at tertiary education level").

Understanding these aspects is critical to help shaping the terms that must govern responsible science and technology policies throughout Europe for the coming decade, mostly if analyzed in comparative terms at international level. In this regard, the paragraphs below aim to discuss critical issues associated with the formulation of science policies in Europe for the next decade, considering the specific nature of each country and national system and taking into account the dynamics of scientific capacity depending and the related accumulation of investment in recent decades (e.g., Ziman, 1978; Conceição and Heitor, 2002).

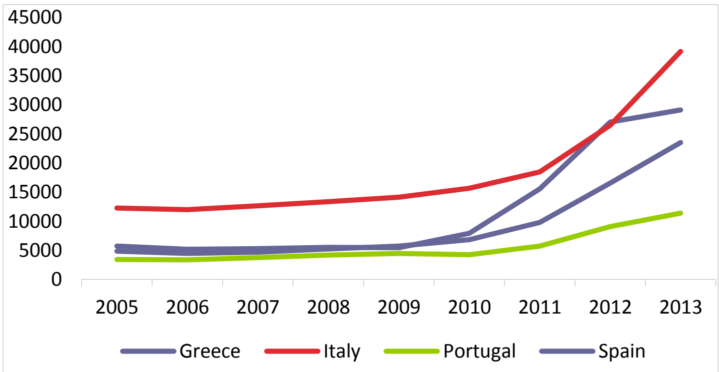


Figure 4 a) Number of people entering in Germany by country of origin, 2005-2013
Source: Statistisches Bundesamt Deutschland, Fachserie 1 Reihe 2- 2005 a 2013

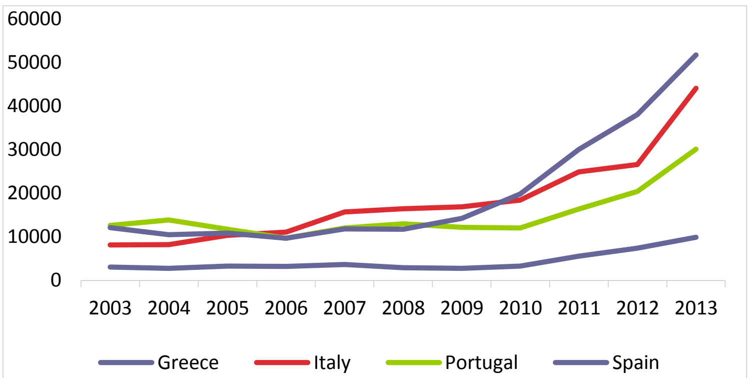


Figure 4 b) - Number of foreigners in UK with a "National Insurance Number", by country of origin, 2003-2013

Source: Department for Work and Pensions – UK

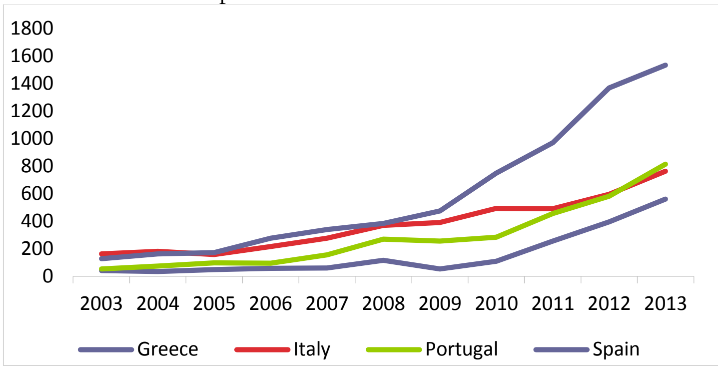


Figure 4 c) - Number of people entering Norway, by country of origin, 2003-2013
Source: Statistics Norway, Immigration, emigration and net migration, by citizenship.
Figure 4 – Flows of people from Southern to Center and Northern Europe, 2005-2013

3. Analysis: the cumulative nature of knowledge

The essentially cumulative nature of knowledge and the dynamics of the investment in that knowledge have served as a basis for the conceptual definition of the terms that may address the theoretical formulation of knowledge-based societies (e.g., Lundvall and Johnson, 1994; Romer, 1994; Ziman, 2000; Nowotny et al., 2001). It is within this framework that the comparative study of science and technology systems and the social construction of knowledge (Bijker et al., 1987) calls for a better understanding of the levels of accumulation of R&D expenditure over a number of years, which influences the performance of those systems (e.g., Conceição et al., 2004).

Figure 5 attempts to introduce this discussion by comparing the accumulated investment per researcher in Europe and Norte America over the last three decades (with reference to 1982) and shows levels of investment in Europe 50% lower than in the USA by 2012. Analysis also shows that the average investment in R&D per citizen in Europe has decreased comparatively to that in USA. The question that arises is about the diversity of political options in Europe as a whole and at the various European member states that have allowed this overall situation. The following paragraphs attempt to clarify this discussion through the analysis of sets of cumulative data.

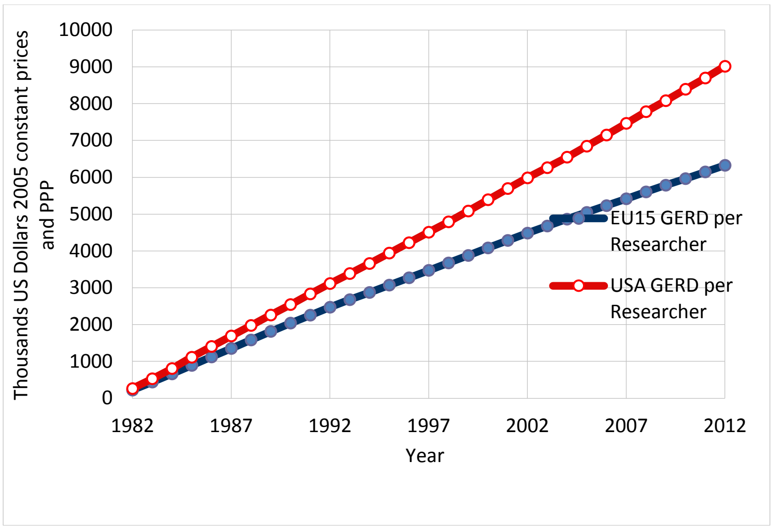


Figure 5 – Cumulative R&D expenditure per researcher, as integrated over the period 1982-2012 (U.S. Dollars 2005 constant prices and PPP). Source: OECD.

3.1 The accumulation of investment in knowledge

Figure 6 compares annual data of total R&D spending per capita (Figure 6a) with cumulative R&D expenditure per capita (Figure 6b) for an extended sample of European countries for the last 30 years. In absolute numbers, at least since 2008, a larger R&D divide is occurring in Europe, with increasingly growing resources in Germany and some Nordic countries, against a relative global reduction of resources in most of the other large EU countries, such as Spain, Italy, France and the UK.

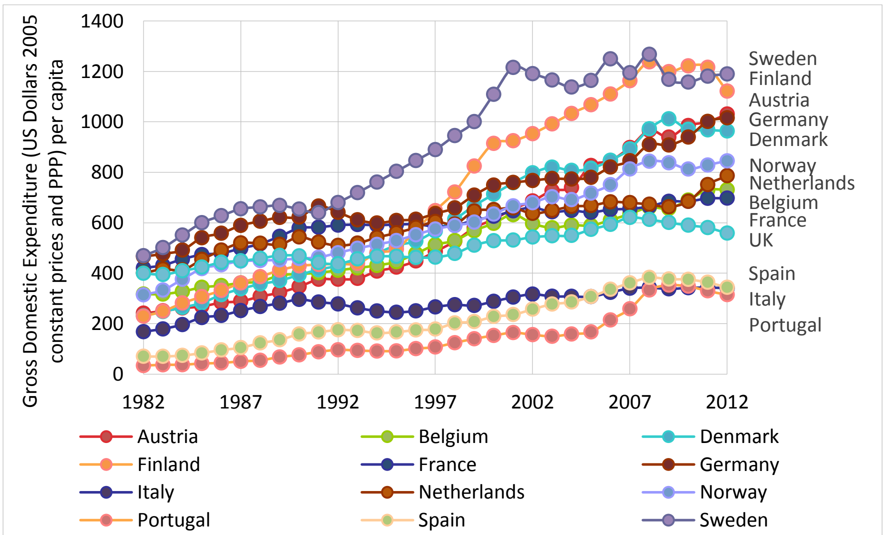


Figure 6a) Annual evolution of GERD/capita in sample of EU countries.

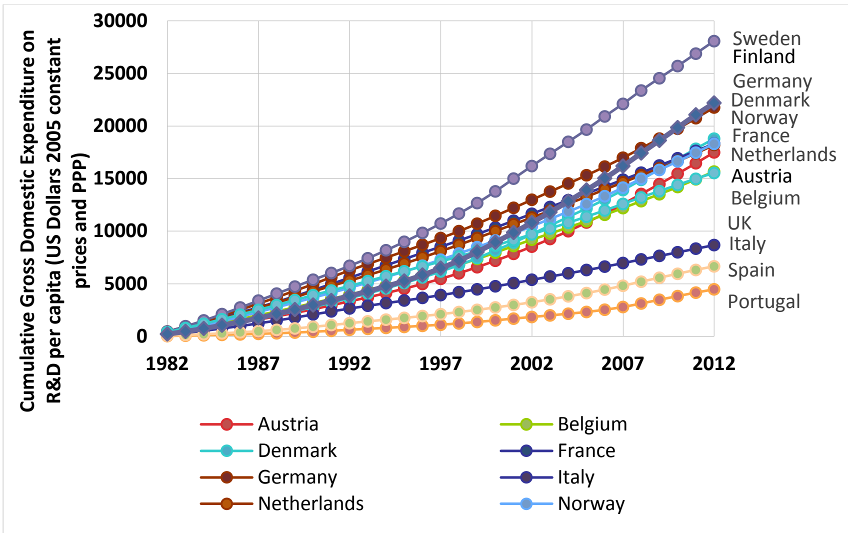


Figure 6b) Cumulative R&D expenditure per capita with reference to 1982 in sample of EU countries.

Figure 6. Annual data and cumulative evolution of R&D expenditure per capita along 30 years in sample of EU countries, 1982-2012 (U.S. Dollars 2005 constant prices and PPP); Source: OECD.

For the smallest countries, the case of Portugal is again worth mentioning. In 2012, Portugal's expenditure per capita was roughly one third that made by the UK and less than a quarter of the typical values for Germany or most of the northern European countries. Despite the impressive growth in the last 30 years in Portugal, with R&D expenditure increasing five times more than GDP, aggregate indicators still stand substantially below those in any other Southern European regions and lag considerably behind those of Northern Europe.

Given the debate that has re-emerged in Southern Europe (among other European peripheries) regarding investment in R&D, we should point out the increasing related divergence to the European average since 2011. On the other hand, Europe shows tremendous internal diversity with an aggregate expenditure per researcher that stands roughly 50% below that of US.

3.2 The impact of S&T policies on human resources

In the context of the analysis above, it is reasonable to ask what has changed in Europe in the last decade? In addition to the number of graduates in science, technology, engineering and mathematics per 1.000 inhabitants (i.e., STEM; Figure 7), where European peripheries (and Southern European countries in particular) underwent the most significant changes within the framework of the OECD, the reinforcement of formal qualifications is confirmed as a distinct feature of some of those countries (e.g., Slovakia, Poland, Czech Republic, Romania and Portugal).

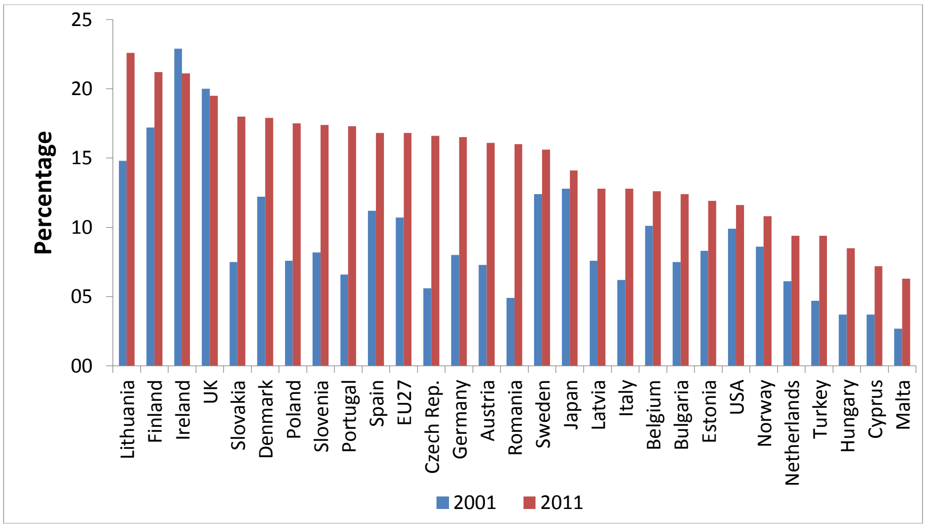


Figure 7 – STEM graduates per 1000 inhabitants with 20-29 years old in a sample of EU countries and the USA, 2012.
Source: EuroStat.

For example, in Czech Republic and Portugal the number of researchers in working population grew by about ten times between 1982 and 2012 (namely from 0.92 to 9.23, in terms of the number of researchers per thousand working population in Portugal). In addition, about 45% of researchers are women in Portugal and the number of researchers in companies was about a quarter of the total number of researchers in Portugal in 2012 (it was less than 10% in 2000, but exceeded ten thousand researchers in FTE in 2012). In addition, advanced training of human resources, as measured in terms of new PhDs per 10.000 inhabitants (Figure 8) has considerably improved throughout European peripheries.

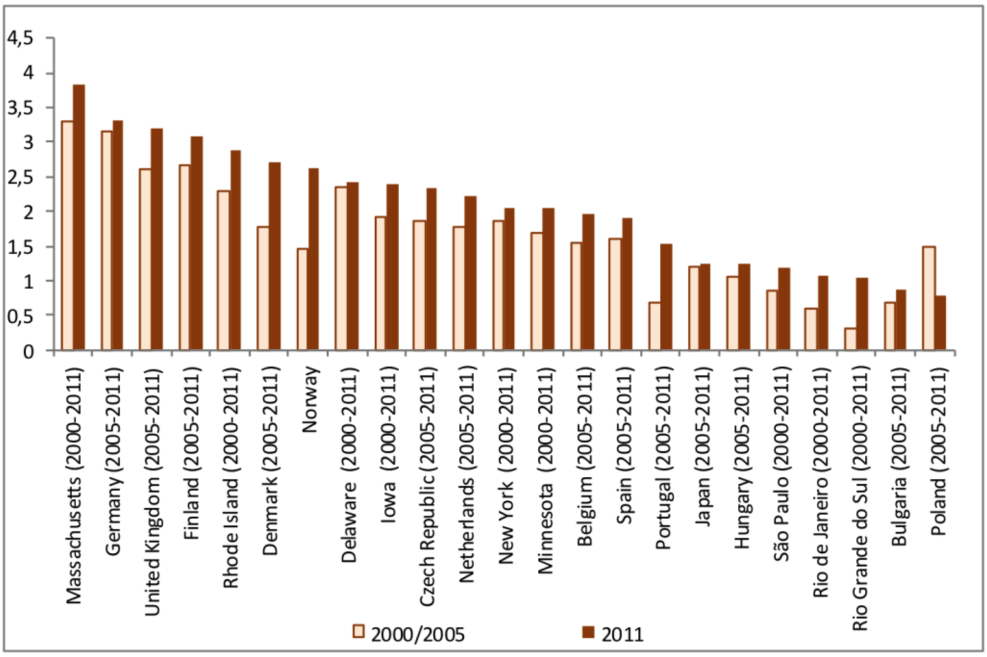


Figure 8 – New PhDs per 10.000 inhabitants for 2000/2005 and 2011 in a sample of EU countries and (North and South) American regions.
Source: EuroStat; UNESCO; INEP; NSF; IBGE; NBS; SSB.NO.

Nonetheless, this scenario contrasts with the overall levels of qualification when measured in terms of the working population. Figure 9 quantifies the evolution of the percentage of working population (aged between 25 and 64) with tertiary education in science and technology fields or of those with a professional activity in which qualifications in science and technology are usually claimed to be held (i.e., “Human Resources in Science and Technology” or “HRSTO” in technical literature), which shows a considerable and persistent deficit in Southern and Eastern European regions over the last decade. For example, whereas in the United Kingdom, the Netherlands, northern European countries and in Europe’s most industrialized regions, the HRSTO accounted for more than half of the workforce, that percentage in most southern and Eastern European regions remains below a quarter of the workforce (namely 24% in Portugal in 2012).

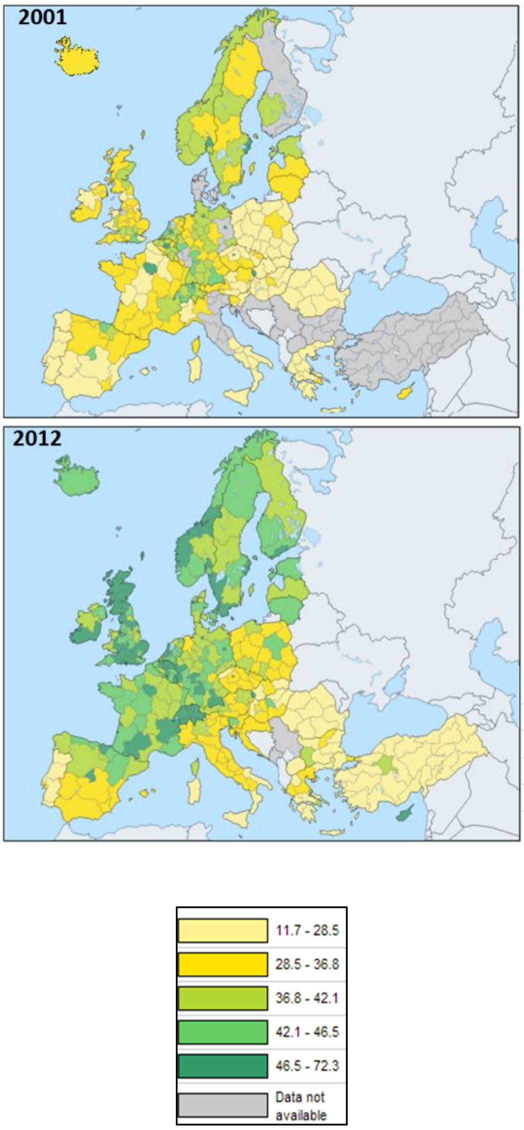


Figura 9 – Human Resources on S&T (“HRST”) in 2001 and 2012 (percentage of active population); Source: EuroStat.

We must therefore try to find out relationships between the R&D effort and the qualifications of human resources and where Southern and Eastern Europe stand in view of the European path as a whole. This issue is discussed in the paragraphs below, together with sample relations with the economy.

4. Discussion: putting the development of S&T public policies into perspective in Europe

How can the scientific community contribute to make Europe, at large, to invest effectively in knowledge production and diffusion and foster a harmonized development of a large and integrated knowledge-based society? And can European peripheries successfully meet the challenges of the coming decades, both in terms of economic, social and cultural development, and their international affirmation?

These questions have driven most of the analysis included in this paper because a polarized debate has emerged in many European regions and countries between an utilitarian perspective of S&T – which enhances the economic relevance of S&T, and a cultural perspective – which stresses the values of independence of S&T in light of the "market" and its critical value for the construction of a national identity. We believe that this polarization of the debate is sterile and that the analysis must focus on the institutional development of the local learning capacities towards socioeconomic growth by reconciling the merits of the two positions. Indeed, Europe at large should seize out this great opportunity and effectively address the developments of S&T over last decades.

Following Latour's (1988) principle of "science and technology in action", our analysis suggest the need to better engaging scientific structures with the civil society, in order to position future experiments towards collaborative policy making and science governance through dialogue. This may include the involvement of scientific communities in 'hybrid forums' (Callon, et all, 2009), where scientists, policy makers and lay people meet to agree the purpose and appliance of scientific knowledge in decisions where uncertainty is at stake. Our hypothesis is, therefore, associated to the concept of "indwelling" firstly introduced by Polanyi (1966) and recently explored by Brown and Thomas (2011) in the context of the "information society". It requires a better understanding of learning societies and policy formulation issues through complex processes of knowing, playing and making.

It is under this context that it has become a commonplace to mention human capital as an essential condition for knowledge creation and dissemination, in a way that any effort towards greater human capital is extremely important for the social and economic development of any part of the world. In itself, this objective calls for policies to expand the social support towards scientific and technological development and the effective appropriation of scientific and technological culture (Majewski, 2013). This obviously requires opening access to higher education through several mechanisms that take into account non-linear people's experiences and life trajectories (Saar et al., 2014).

A simple estimate of students, aged between 20 and 24, who are currently attending higher education, in addition to those that already hold an advanced academic degree, and keeping the current higher education completion rates, makes us assume that all

European regions will achieve 30% of graduates aged between 30-34 by 2020 (Heitor et al. 2014). Consequently, in order to meet the European Strategy 2020 goals, which entails achieving 40% of graduates in that population group by 2020, it is necessary that many more thousand of students aged between 20 and 24 all over Europe conclude their graduate studies, beyond the current graduation levels.

The analysis still shows that the success of opening higher education within the framework that emerges at international level, in which innovation must be considered together with competence building and advanced education, calls for complex interactions between formal and informal qualifications (Helpman, 2004). This requires continuation of a major effort at a wide European level to broadening the social basis of knowledge-based activities and strengthening the "top" of the knowledge production system.

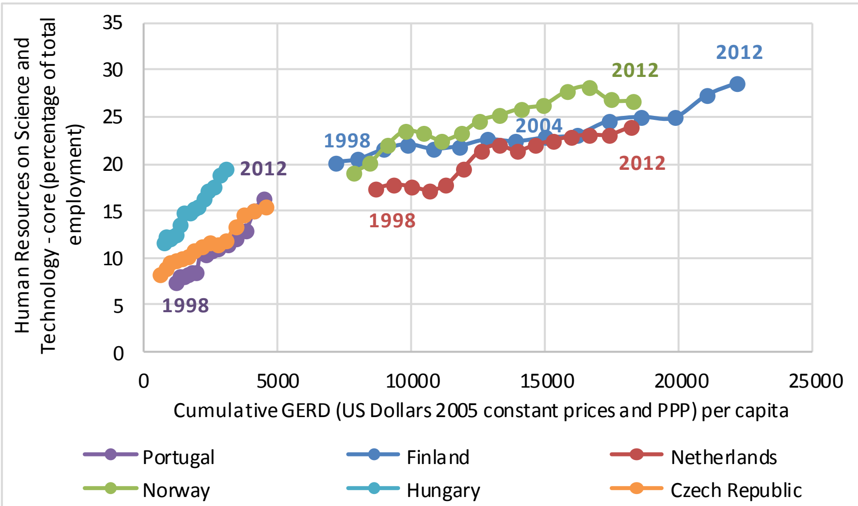
If we try to develop further the implications of this argument and the terms which must drive the formulation of national S&T policies across Europe, it is obvious that three vital issues must be addressed: a) scale, especially when it comes to the undeniable need to increase public efforts in S&T; b) diversification, namely regarding the need to perceive the difference between instruments and the role of public and private funding; and c) time, regarding the need to understand a continued effort in S&T. These terms are further discussed in the following paragraphs in order to better understand the development of public policies across Europe and put their future development in perspective.

4.1 The basic assumption: linking public investment in science and technology to the systematic reinforcement of human capital

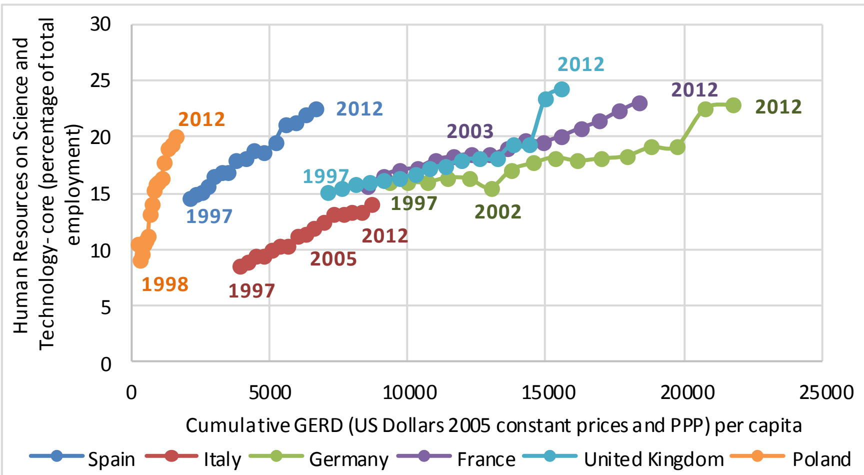
Within a framework of high volatility of a fast-changing society and economy – as it always has been – and at a time where increasing socio-economic inequalities are observed throughout Europe, one should conclude (perhaps counter-intuitively) that the system must go on expanding and diversifying in order to meet the quantitative and qualitative needs of the future. The analysis must consider the need to cover an increasing diverse population, the demands of society and of volatile and highly uncertain markets.

Figure 10 complements and expands the analysis of the previous section and relates the development of total "Human Resources in Science and Technology" (or "HRSTO" in technical literature) to the accumulation of gross expenditure in R&D over the last decade. It shows that R&D investment efforts in many EU countries, including Hungary, Czech Republic and Portugal (as small and medium EU countries, Figure 10a) and Spain, Poland and Italy (as large EU countries, Figure 10b) were particularly important to qualify people. Nevertheless, those investment efforts still remain relatively tiny, compared to other small and medium-sized countries. For example, Norway, Holland and Finland have made considerably higher accumulated investment efforts in R&D than those "less mature" countries and are characterized today by a comparatively highly qualified workforce.

Within this framework, our analysis suggest that the formulation of S&T policies in the countries identified above with relatively lower levels of accumulated expenditure in R&D should keep on being targeted particularly to foster advanced education of human resources, by encouraging the qualification of human capital. This is because those countries have evolved considerably in terms of the number of researchers and the education level of their young people in recent decades, but still have a long way to go in terms of qualifying their workforce, mostly in a context of increasing competition for qualified human resources at an international level. For example, the unprecedented increase in the level of emigration from southern to northern Europe since 2010 (Figure 4) reveals unsustainable migratory paths in Europe that are affecting the performance of Europe as whole, with short term implications that are augmenting the European divide identified above in this paper.



a) Sample of small and medium EU countries.



b) Sample of large EU countries.

Figure 10 – Human Resources in S&T (core coverage) versus cumulative gross expenditure in R&D, GERD (1998-2005);

Notes: HRST in percentage of total employment, GERD per capita in U.S. Dollars 2005 constant prices and PPP; HRSTC - Core refers to those people who have successfully completed education at the third level (HRSTE) – ISCED levels 5 and 6 and are employed in a S&T occupation (HRSTO) – ISCO major groups: 2 (professionals) and 3 (technicians); Source: OECD, EuroStat.

In this context, the case of Poland, Spain and Italy should be highlighted, as Figure 10b) illustrates, namely in terms of the low level of aggregate investment in R&D compared to other large EU countries, particularly Germany, France and England.

At this stage it is important to mention Goldin and Katz (2008), among others, regarding the role of education in economic growth and the direct relationship between the qualification levels of nations and their aggregate growth rate (see also, OECD, 2008). Recently, the 2006 Nobel Prize-winner in Economic Sciences, Edmund Phelps (2013), also revisited this debate and shown that prosperity growth is associated with values such as the wish to create and explore new challenges, and is not fuelled by some secluded visionaries (such as Henry Ford or Steve Jobs), but by millions of qualified people thinking and developing new products and processes, as well as systematically putting improvements in place for those that already exist. Phelps (2013) coined this process as 'mass flourishing'.

It should also be made clear that is not possible to conclude from our analysis that economic growth is a simple matter of investing in education or in S&T. Nonetheless, it is also clear that investing significantly in education over time leads to greater levels of qualification of the workforce and productivity, helping economic growth and improving the quality of life. Goldin and Katz (2008) have shown that the benefits of economic growth may be distributed unevenly and an average pattern of high quality of life may not lead to improvements for all. The implications of these observations for southern and eastern European nations are relevant, especially to consider the challenge to promote equity in access, social mobility and the capacity of provision of a mass and diversified tertiary education system, for which the effort in S&T is a decisive factor (e.g., Heitor and Horta, 2014).

In light of the foregoing, the basic assumption considered in this paper for the design of science policies is based on the need to systematically reinforce human capital. In fact, science, its impact and particularly innovation, which nowadays gives us so much cause for concern, result from a cumulative process that has gained roots over collective and mostly uncertain learning processes (Conceição et al, 2003), involving above all an extensive division of labour (Mazzucato, 2013). And this implies the need to effectively consider the qualification of the workforce within a broad range of economic sectors.

It is also important to clarify the potential for growth of human resources in science and technology in Europe. Despite the rapid growth of human resources in S&T over the last 30 years, there is still a high growth potential and, above all, the need to further develop this growth process. For example, human resources employed in science and technology occupations (i.e., "HRSTO") in Portugal and many other European peripheries account for less than a quarter of the workforce in the age group 25-64, whereas, in 2012, this share was around 40% for the EU-27 average and more than 50% in Holland, Finland or Denmark, as well as in Europe's most industrialized areas.

4.2 Understanding the impact of S&T policies on the economy: diversification and internationalization

I won't spend much effort convincing the readers of the importance of R&D investment for long-run economic growth. The Nobel Prize-winning economist Robert E. Lucas, Jr., wrote that once one starts thinking about long-run growth and economic development, "it is hard to think about anything else."

Although I don't think I would go quite that far, I should note that the primary economic rationale for a government action in R&D is that, absent of such intervention, the private market would not adequately supply certain types of research and skill development (Arrow, 1962; Romer, 2000). The argument, which applies particularly strongly to basic or fundamental research, is that the full economic value of a scientific advance is unlikely to accrue to its discoverer, especially if the new knowledge can be replicated or disseminated at low cost (Conceição et al, 2004). For example, James Watson and Francis Crick received a minute fraction of the economic benefits that have flowed from their discovery of the structure of DNA. If many people are able to exploit, or otherwise benefit from, research done by others, then the total or social return to research may be higher on average than the private return to those who bear the costs and risks of innovation. As a result, market forces will lead to underinvestment in R&D from society's perspective, providing a rationale for government intervention.

But it is not a trivial matter to understand the processes that enable investments in R&D and human capital to be transformed into productivity gains. Actually, there is a widespread view among economists that this kind of investment is too costly for the economic efficiency gains it provides.

This however is a too naïve and superficial approach. Viewed from a wider perspective, in the longer term R&D and human capital investments do matter and are probably the most important factor in explaining economic growth. However, the naïve view has a point: it is not automatic the transition of human capital to growth. Specific actions are needed to make this transition happen successfully.

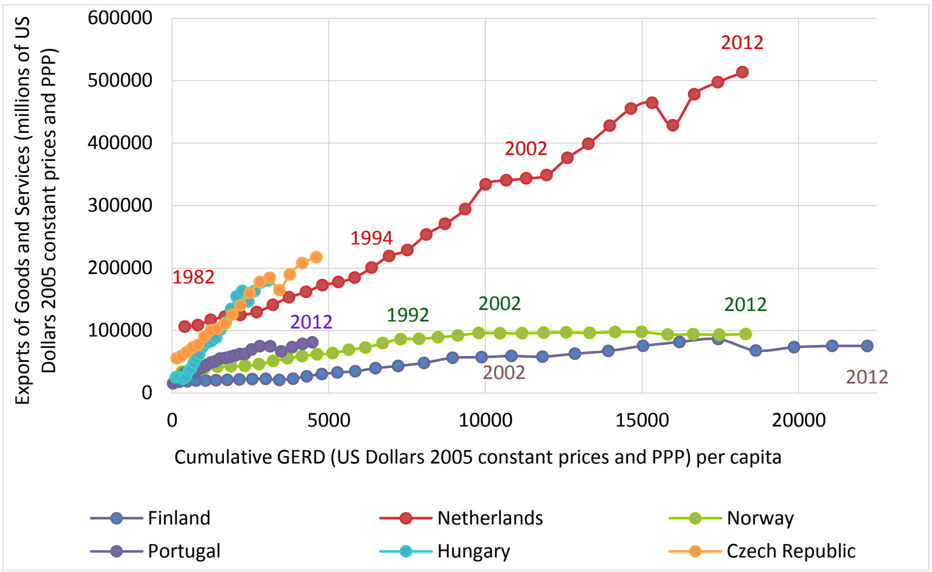
It is under this context that the technical literature is clear in that economic development and its relation with R&D are increasingly understood as a combination of learning processes, at all levels: individual, organizational, and national (e.g., Ziman, 1978; Romer, 1994; Conceição et al, 2003; Mazzucato, 2013). Thus the issue is to try to understand why and how some people, firms, and countries learn, while others do not. Diversity and heterogeneity across individuals and countries will always surely entail some level of inequality in learning performance. Still, the dimension of the gaps and the size of European (and world) inequalities warrant a search on the reasons why some do learn so well, while others seem to lag, even acknowledging for the idiosyncrasies that will always lead to some differentiation across individuals, organizations, and countries.

When focusing on regional and national learning, the first question to address is who are the actors of the learning processes and how is the knowledge that is accumulated translated into economic wealth. As we suggested above, learning at the aggregate level of a region or country is likely to depend on many types of learning at different levels, from people to organizations. But it should also be clear that this has been perhaps the argument mostly used in many European countries to reverse policies and/or reduce investment in S&T in recent years (e.g., Mazzucato, 2013).

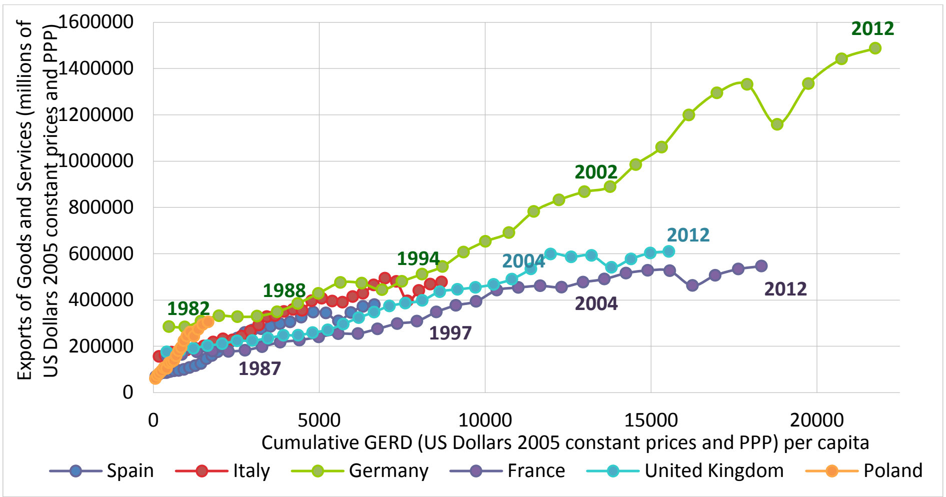
It is important, however, to note that, despite the current growing financial vulnerability of many European regions, the accumulation of investment in S&T over the last 30 years has allowed to offset the technological balance and increase exports in those regions. It was in this context that the evolution of business expenditure in R&D in Spain, Czech Republic, Portugal and many other countries reflects increasing private sector efforts in valuing scientific and technological capacities, namely in terms of innovation potential and access to emerging markets worldwide.

To help clarifying this discussion, Figure 11 relates the evolution of total exports for the past 20 years with the accumulation of the gross expenditure in R&D over that period in a sample of small, medium-sized and large European countries.

The results suggest that R&D investment efforts have been particularly critical to help the most industrialized countries fostering their exports. This is certainly the case of The Netherlands and Germany, as well as UK and France, with the notable figure of Germany that increased its level of exports by four times after 30 years of consecutive investment in R&D. The related correlation of R&D and the access to external markets in Czech Republic and Hungary is also worth noting, as well as in Portugal, although at a lower level. Nevertheless, the analysis clearly shows that these investment efforts still remain relatively low in many European countries. For example, for an investment effort in R&D similar to that of Portugal, the Czech Republic more than doubled its share of exports.



a) Sample of small and medium EU countries.



b) Sample of large EU countries

Figure 11 – Total exports versus R&D accumulated expenditure per capita (millions of U.S. Dollars 2005 constant prices and PPP); Source: OECD.

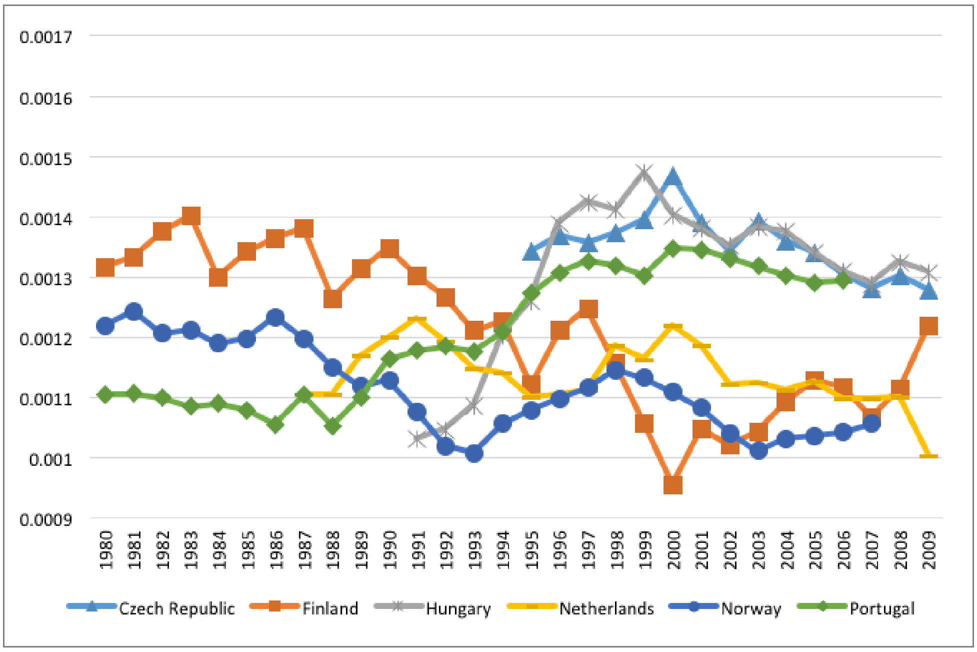
Figure 12 helps clarify the reason behind the success of Germany and The Netherlands in terms of the impact of R&D on exports, by showing that those two countries are those that have been able to better diversify their economic structure in recent decades. The figure quantifies the level of economic structure diversification through the inverse of the Herfindahl-Hirschman Index for economic structure (considering industrial output, or manufacturing, only; see, for example, Waterson, 1984), which is defined as the inverse of the sum of the square of the market share of the various industrial sectors operating in the economy. It therefore allows for analyzing the relative levels of concentration/diversification of industrial activity, showing that the impact of R&D activities accumulated over the years is mostly contingent upon the structure of the economies.

In other words, the analysis suggests that only those European nations that have increased the investment in S&T and managed, at the same time, to diversify their economic structure have fully guarantee the necessary absorptive capacity to foster the impact of S&T in economic development (see, for example, Cohen and Levinthal, 1990; Freel, 2005; and Vinding, 2004). The implications for southern and eastern European countries are notorious and call for the need to combine the need to increase the budget allocated to R&D with measures oriented towards technological diversification and intensification of the industrial base across different sectors.

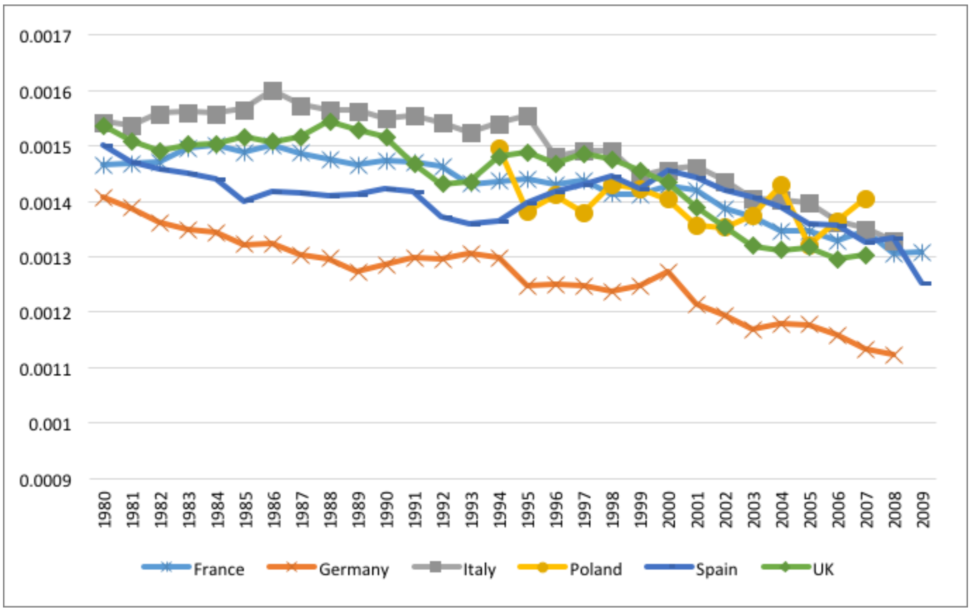
It should also be noted that the concepts of economic diversification and the related development of a sustainable industrial basis, in addition to being distinctive features of the most developed economies, are also associated with the development processes of the countries that have become direct competitors of Western economies in recent decades, such as South Korea (Amesden, 2001) or Taiwan (Berger, 2005).

Diversification, in particular, seems to allow for economic growth of countries and regions, mostly because of the increase in consumption. It is also important to the extent that the weight and, therefore, the dependence on the economy of each industrial sector have lost ground. Because almost all knowledge-intensive exports are associated with high-tech manufacturing industries, investment in those industries should also allow for mitigating the risk of regional crises, in that it becomes possible to look for potential markets in other regions.

By doing so, diversification is associated with the creation of socioeconomic resilience, i.e. the ability of the socioeconomic fabric, and companies in particular, to promote themselves and recuperate from financial shocks, such as recessions or crises. Nevertheless, the processes related to industrial diversification and specialization, which are linked to competence broadening and development, respectively, are extremely complex and mostly associated with knowledge and technology learning and incorporation processes in people and organizations (Sheffi, 2007).



a) Sample of small and medium EU countries



b) Sample of large EU countries.

Figure 12 – Levels of diversification of economic structure: 1980-2010, as quantified by the Inverse Hirshman-Herfindahl Index for the economic structure (only manufacturing); Source: OECD.

Against this background, competitiveness in most industrial sectors hides the capacity of getting access to and using knowledge developed in a wide and diversified range of institutions that constitute distributed knowledge bases, requiring "learning infrastructure" that facilitate interface activities between industry and those bases (Romer, 1994).

Job creation and quantification is a key issue of the local socioeconomic impact of industrialization processes and, consequently, in the context of the previous analysis, sustainable development of technological and industrial bases calls for building distinctive competences. This process must be based on qualified human resources and investment in R&D, thereby contributing to continuously develop those competences, gain experience and, therefore, may help build up competitive advantages (Cohen and Levinthal, 1990).

The analysis suggests the need to continuously assess the potential for growth of technological intensity in European peripheries, namely in terms of the participation of the private sector in efforts to increase local technological intensity. On the other hand, it also suggests that large companies need to increase significantly their investment in R&D in order to optimize scientific employment routines in the private sector, along with the specialization of their skills. In particular, public policies and regulatory frameworks should be oriented to stimulate consortia of market leading companies oriented towards increasing national exports as a way to allow companies to enter emerging markets more easily.

It should also be noted that R&D outcomes tend to be characterized by strong spill-over effects, i.e., the benefits for those who carry out R&D go well beyond the investing entity. From the point of view of companies, this leads to an underinvestment in R&D, because there is no full appropriation of benefits of that investment (Conceição et al., 2004). The conclusion is that public policies geared for increasing private expenditure in R&D should embrace increasing public expenditure, which is counter-intuitive in light of a "linear" interpretation of the innovation generating mechanisms. Nevertheless, that is a right conclusion considering the characteristics of R&D in its complex relationship with economy, technological innovation and scientific development (Romer, 1994; Lundvall and Johnson, 1994). It is well known that, when tracking the trajectory of the countries that today most invest in private funds in R&D, it can been seen that this outbreak has been historically preceded by high and sustained public investments in R&D (e.g., Conceição et al., 2004; Mazzucato, 2013).

4.3 On the role of Public Policy

It is well documented in the technical literature that it is research done in a business setting that most directly relates to the emergence of new products likely to be exported to global markets and that most contributes to productivity growth and boost competitiveness. But the main issue is that we know on a global scale that the best strategy to increase spending executed and funded by companies consists in a strong and sustained growth of the public funding of R&D, namely in universities (e.g., Conceição and Heitor, 2002; Conceição et al., 2004; Mazzucato, 2013). This statement is apparently counterintuitive. Broadly speaking, public spending drives down (or crowds out) private spending. If the State builds a road next to the door of a new factory, the company that invested in the factory will not build the road: therefore, there is a crowding-out effect.

But our point is that there is no crowding-out effect of private expenditure when it refers to university-based scientific research. Research done in universities and scientific institutions translates not only into new outcomes in science and prepares academic staff and new doctorates, but also experts and skilled labor force. This is one of the most important mechanisms that contribute to answer the needs of companies and the labor market in terms of skills and competences required to technical change and related wealth creation. Academic-based research has increasingly given way to new high-tech companies, which create jobs and generate exports.

Although the functions that are socially allocated to scientific institutions start being shared by a wide spectrum of institutions, public policies are now faced with demands for an increased presence of the State to promote knowledge creation and dissemination (Mazzucato, 2013; Stilgoe, 2013). In fact, we could also argue on the exclusive role that public policies should take on to ensure system diversification, inter-institutional mobility, initial cooperation with companies, as well as institutional integrity and internationalization. However, one must remember that the role of public polices as guarantor of institutional diversity and integrity must be implemented through funding and assessment mechanisms.

The indicators used in this study show that the average funding rate per researcher in most southern and eastern European countries continues to be a third of that in the most industrialized European countries, and a researcher in higher education in Europe has approximately half the funding of a researcher in the US. Comparatively, the level of GDP per capita in most southern European regions (e.g., Portugal and Greece) is about 75% of the average share for Europe which shows an effective deficit of R&D funding in those regions, particularly in cumulative terms.

The importance of this discussion lies in the fact that several models of economic growth have allowed for explaining the increase in per capita income in developed countries depending on the degree of knowledge accumulation, which has provided grounds for considering S&T evolution as endogenous to economic and social development (Romer, 2004; Conceição and Heitor, 2002). Within this framework, there has been in recent literature the need for considering institutions and policies in order to explain cross-country differences in terms of knowledge and per capita income generation.

Nevertheless, knowledge creation and dissemination acceleration intensity requires a more in-depth characterization, because the critical aspect is associated with a dynamic perspective, as analyzed by Conceição et al. (2003) in a European context. According to these authors, there is not only knowledge that becomes really important, but also knowledge that become less important. There is both knowledge creation and destruction, which forces us to understand knowledge creation and dissemination processes. In short, sustainability growth of the economy and the learning society in which we live is a task that goes beyond traditional challenges. Changes in workforce composition, along with the ever-increasing internationalization of economy, the constant advances in technology and dissemination of new innovative labor organization models, call for a substantial investment in human capital so that the requirements in terms of skills and qualifications of future employment are met.

In this respect, we cannot expect that the private initiative, per se, increases R&D activity and solve the issues of employment and wealth in Europe. The need that emerges for diversifying mechanisms to foster S&T and stimulate innovation requires public policies that promote scientific employment in association with areas of large public and private investments. Public policies are also critical to mobilize public resources in S&T, allowing qualified people and knowledge to be available to conduct R&D in companies.

5. Summary

This paper argues that public policy formulation in Europe, after a decade hit by recession and economic and budgetary problems, must take into account countercyclical measures, while focusing on advanced education of human resources and strengthening S&T in all branches of knowledge. The continuous qualification of the workforce at large is a persistent challenge that requires broadening the social basis for advanced education, as well as for further internationalizing knowledge and innovation networks.

Science, together with its dissemination and social and economic appropriation, needs time. Furthering the debate on the role of public policies in economic competitiveness, giving priority to knowledge and technological change in the course of a hard economic and budgetary adjustment program at international level is undoubtedly a huge challenge and requires the mobilization of all.

Why is it not trivial to understand that investing in S&T creates jobs and exports and is indispensable for long run growth in modern economies and societies? This question is increasingly relevant because, in recent years, it has been very important to place many European countries and regions on track with EU average investment levels in R&D, but this remains insufficient. In addition, the accumulation of that investment in many European regions and countries is still very low, if compared to any industrially developed region, particularly in the USA.

Our analysis shows levels of accumulated investment per researcher in Europe 50% lower than in the USA by 2012 and that the average investment in R&D per citizen in Europe has decreased comparatively to that in USA. In addition, the paper argues that only those European nations that have increased the investment in S&T and managed, at the same time, to diversify their economic structure have fully guarantee the necessary absorptive capacity to foster the impact of S&T in economic development. The implications for Europe is notorious and call for the need to increase the budget allocated to R&D all over Europe with measures oriented towards technological diversification and intensification of the industrial base across different sectors.

In short, the increase in R&D expenditure carried out in universities and firm is not inevitable, but a choice. European citizens at large and their governments must make this choice, and it is important that they are aware that if we do not continue to grow in those areas, it will be difficult to encourage technological innovation and economic competitiveness. In order to achieve these objectives, it is paramount to mobilize and employ more PhD graduates throughout entire Europe, foster research in universities, strengthen the relationship between universities and the business sector, and guarantee scientific and technological relationships with the leading institutions worldwide. And this can be only achieved if we simultaneously stimulate demand and supply of the ability of carrying out R&D.

The current level of European economic and technological development requires a major and sustained effort of public funding of R&D across all over Europe. This will contribute not only to graduate new PhD students and foster scientific employment, but also, directly and indirectly, to foster demand. This has been the way regions and countries with high levels of R&D and a large percentage of business R&D have followed. The faster Europe at large addresses this challenge, the quicker it will be kept up with.

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