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Working Paper Series No. 5

THE RESEARCH OUTPUT OF UNIVERSITIES AND ITS DETERMINANTS: QUALITY, INTANGIBLE INVESTMENTS, SPECIALISATION AND INEFFICIENCIES

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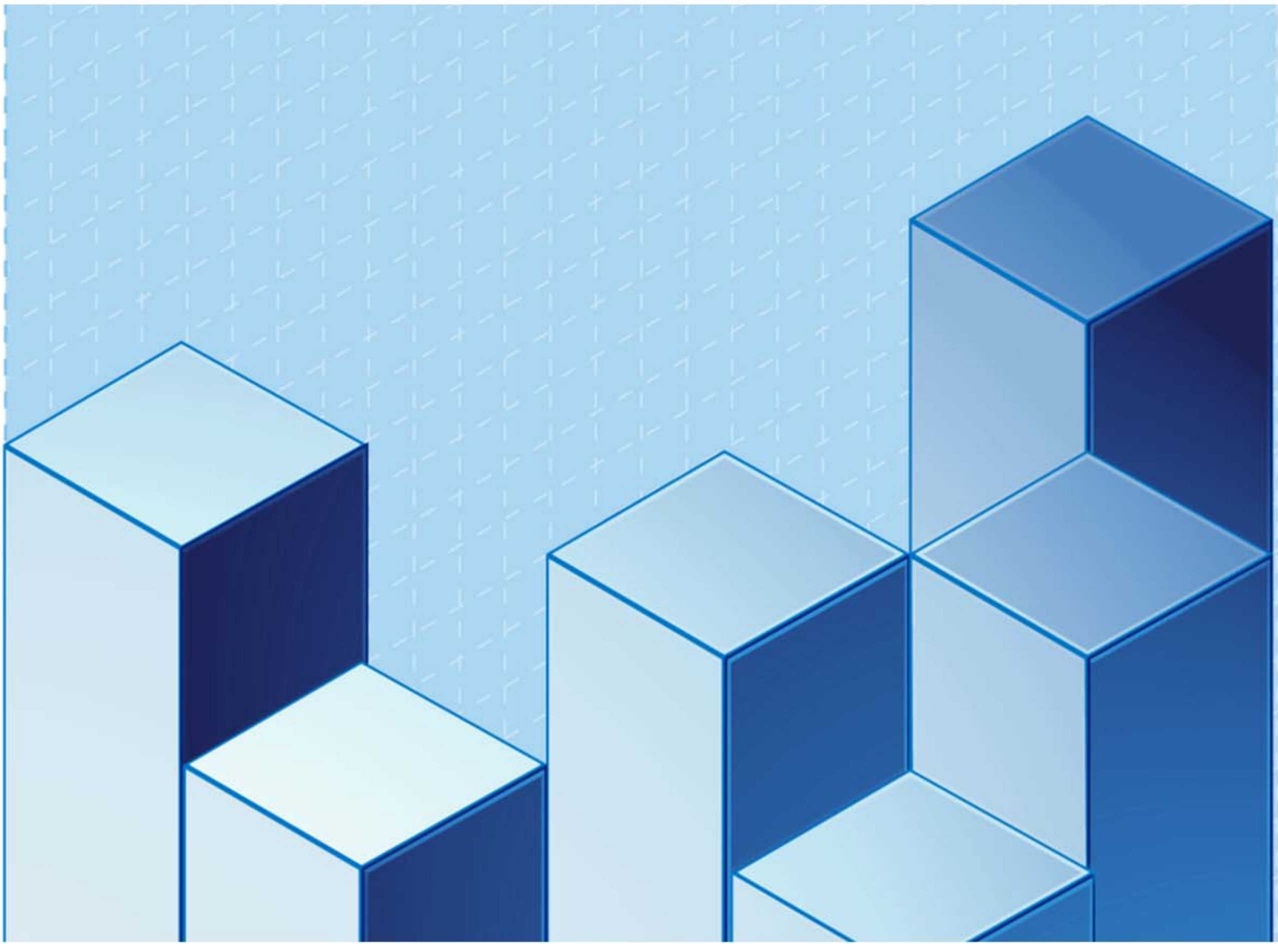

SPINTAN Project: Smart Public intangibles. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no: 612774.

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Version: March 2016

Published by:

Instituto Valenciano de Investigaciones Económicas, S.A.
C/ Guardia Civil, 22 esc. 2 1º - 46020 Valencia (Spain)

DOI: http://dx.medra.org/10.12842/SPINTAN-WP-05

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THE RESEARCH OUTPUT OF UNIVERSITIES AND ITS DETERMINANTS: QUALITY, INTANGIBLE INVESTMENTS, SPECIALISATION AND INEFFICIENCIES*

José Manuel Pastor
Lorenzo Serrano**

Abstract

Increasing research output is a fundamental challenge for the well-being of European citizens. The analysis of productivity in Higher Education Institutes (HEIs) at a European level reveals enormous differences in output per researcher across countries. This study develops a 5-step methodology that explicitly considers the quality of scientific output in EU universities and its specialisations to explain and decompose the differences in output per university teacher in terms of a) differences in efficiency within each field of science (FOS), b) differences in FOS specialisation of the HEIs in each country, c) differences in quality, and d) differences in allocation of resources per researcher. The inefficiency levels estimated show that across the EU as a whole there is a substantial margin for increasing research output without having to spend more resources. There are also major differences between countries in terms of inefficiency. The main sources of heterogeneity in scientific output from the HEIs in the EU are the differences in resources allocated per researcher and, to a lesser extent, the differences in efficiency within each knowledge field. In contrast, the differences in quality and in specialisation seem to play a much smaller role in determining differences in output.

* This paper was developed as part of the SPINTAN project funded by the European Commission. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no: 612774.

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1. INTRODUCTION

It is widely accepted that a country's capacity to generate wealth and achieve high levels of well-being is closely linked to its capacity to generate knowledge. Knowledge is the basis for innovation and an essential requirement for increasing production in modern societies.

In the EU the generation and transmission of knowledge essentially falls to higher education institutions (HEIs). HEIs account for around 23.7% of all R&D expenditure and generate about 64.3% of all scientific publications and 2.9% of all patents. HEIs produce knowledge through research, they disseminate it by training graduates and postgraduates and by publishing the results of the research, and they transfer it via collaboration agreements with companies and institutions. HEIs are a cornerstone in developing today's knowledge society as they are the only institutions that participate in both the creation of knowledge and its dissemination and transfer.

The role of HEIs in today's knowledge society and their contribution to regional socioeconomic development[1] is of such importance that it is appropriate to evaluate and contextualise their levels of productivity; in other words, evaluate how much scientific output they obtain for the resources they use, analyse whether there are major differences between countries and find out what determines these differences. The first step to this end is to define the output of the HEIs.

However, measuring HIE output is highly problematic for the following reasons: a) HIEs undertake various activities at the same time (teaching, research and knowledge transfer); b) diverse outputs are produced within each of these activities at the same time; and c) the quality of the outputs can vary greatly, making it necessary to consider output quality as well as quantity.

The problems of measuring the output of these services sector activities (education and research) represent a dual challenge for national and international statistical agencies, since a) there is no consensus about the appropriate indicators to use and b) the output indicator selected should reflect the considerable improvements in quality that are taking place, by substituting current indicators based on inputs (cost) for others based more on the outputs and outcomes of their activities (Pastor, Serrano and Zaera, 2015).

The aim of this study is to analyse what determines the differences in scientific output per researcher in the HEIs of EU countries. To this end we develop a methodology that specif-

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[1] Pastor and Peraita (2012) offer a review of studies of the socioeconomic contribution of universities.

ically considers the quality of scientific output from universities and their different specialisation according to field of science and technology (FOS). This methodology can be used to break down the differences in scientific output per researcher among the HEIs of each country in terms of a) differences in efficiency within each field, b) differences in FOS specialisation of the HEIs in each country, c) differences in quality and d) differences in allocation of resources per researcher.

The study is organised as follows. Following this introduction, Section 2 reviews the problems of measuring university activity, compiles some proposals from the literature, reviews the main existing problems and presents the proposal for a research output indicator. Section 3 describes the data used. Section 4 examines the importance of HEIs in EU research activity, evaluates the differences in scientific output among the EU countries and demonstrates the importance of approaching the problem in a disaggregated way in the different fields of science. Section 5 describes the methodology used. Section 6 very briefly presents some of the results obtained on the different components of inefficiency. The study ends with the main conclusions in Section 7.

2. MEASURING HEI RESEARCH OUTPUT

Researchers who analyse HEI research output face several problems. First, universities undertake various missions simultaneously (teaching, research and technological transfer). Second, the productive processes of the missions of HEIs are multiproduct. Hence, for example, HEIs produce various teaching outputs at the same time (graduates, post graduates, etc.), various research outputs at the same time (publications, patents, etc.) or various technological transfer outputs (contracts with firms, technological assistance, etc.).[2]

There is a fairly general consensus that universities' teaching output can be reasonably measured by the number of graduates or number of students.[3] However, there is no consensus among experts about which are the most appropriate indicators to measure HEI

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[2] See Johnes (1996), Salas (2012) or Pastor et al. (2015).

[3] Some studies propose the additional use of diverse indicators of the quality of university teaching, such as the drop-out rate, the performance rate, the student-teacher ratio, expenditure per student, the number of information technology (IT) and library staff per student, expenditure per student, etc. See FCYD (2008), Salas (2012) or Pérez et al. (2015). At the aggregate level, there are also proposals for contemplating the differences and/or improvements in the quality of teaching activity through the use of salaries, under the assumption that, *ceteris paribus*, higher graduate salaries reflect a greater quality of the education received. On this question, see Mortensen *et al.* (2011).

research output activity. The most frequently used research outputs in the literature are publications, citations and, to a lesser degree, patents.[4]

The problem arises when we want to analyse universities' research output using only one indicator, either publications or patents, since by doing so we do not take into account the multiproduct nature of HEIs, and therefore ignore the results of a significant part of their research activity.[5] Thus, for example, if we consider the number of publications in scientific journals as the only output, we would not be capturing the research activity from other areas that are not manifested in terms of publications (e.g., patents), and as a result we would be underestimating the research output of universities whose research activity is reflected more in terms of patents than publications.

Figure 1 shows the different orientation of research activity in the HEIs[6] of the EU-28 countries. The two lines in the figure represent the arithmetic average of publications and patents per researcher for the 28 member states of the EU and delimit four quadrants. The figure shows the coexistence of different university systems in the EU-28 such as those of France and Germany oriented to the production of patents located in quadrant I (all with more than six patents for every thousand researchers) alongside university sys-

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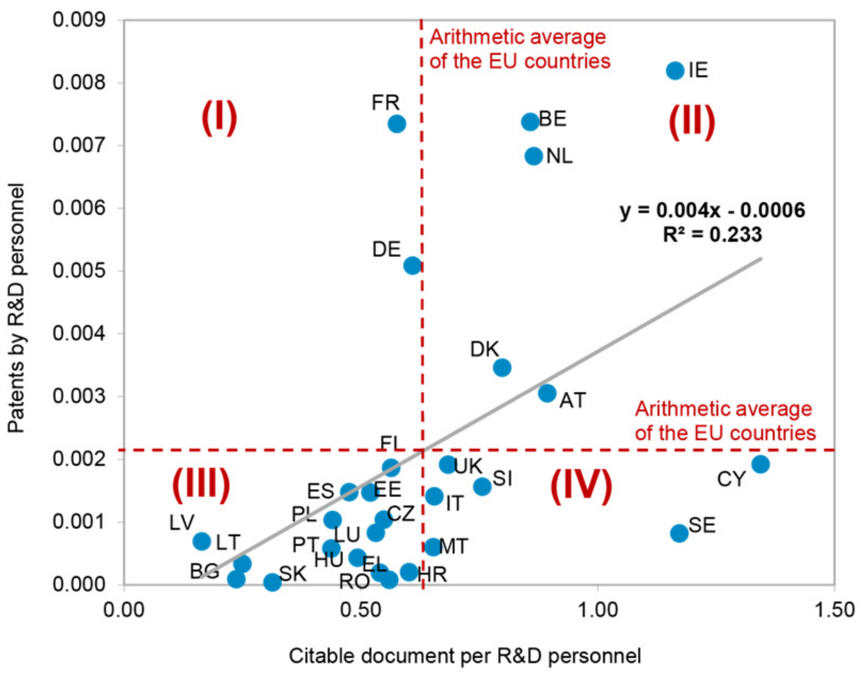
[4] Some authors use complementarily variables such as the revenue from R&D projects, doctoral theses, or number of teacher training grants. Ryana (2012) uses the number of patents and analyses the determinants. Breneman *et al.* (1976), Azoulay *et al.* (2007) and Ryana (2012) use the number of PhDs awarded by universities. Salas (2012) and Banal-Estañol *et al.* (2011) employ the number of articles and the number of projects. However, their use as indicators of *research output* is controversial. Thus, the revenue from R&D projects is at the same time *inputs* and *outputs* of research activity and their use is not completely justified, insofar as data regarding scientific production are directly available. Equally, the number of doctoral theses is also debatable, insofar as if they are of sufficient quality they will assuredly produce satisfactory results in the future (Pérez-Esparrells and Gómez-Sancho 2010), and thus the same output would be counted twice (in the present and in the future). Finally, the number of teacher training grants does not have a direct relationship with scientific productivity and is more closely related to teaching, since it depends on the academic records of the students to whom they are awarded (and the size of universities) and, as with research projects, could be considered as an input.

[5] This problem is similar to that faced by researchers who compile university rankings. In this case the intention is to summarise in a composite indicator the set of activities undertaken by universities. If teaching indicators predominate in the set of variables selected for the elaboration of that composite ranking or if they are assigned an artificially heavy weight, the results will be biased in favour of universities oriented towards teaching, to the detriment of those with a research orientation.

[6] Data provided by SCIMAGO Journal & Country Rank refer to the total number of scientific publications produces by a country. 99% of the EU-28's scientific output comes from universities (64.3%), Public research centres (22.8%) and Hospitals (11.8%). For this reason the data on patents, publications, citations, R&D expenditure and R&D personnel provided throughout this paper refer to Higher Education (universities) and Government sector (Public Research Centres and Hospitals) as a whole.

tems with a much stronger orientation to produce publications, located in quadrant IV, such as Sweden and Cyprus (with more than 1.2 publications per researcher). However, the most striking revelation is that within the EU there are university systems that stand out for their excellence in both types of research output (quadrant II) and others with poor results in the two indicators (quadrant III). The first group, made up of Ireland, Belgium and Netherlands, stands out for excellent performance in both indicators. At the opposite extreme are university systems from countries in Eastern Europe such as Slovakia, Latvia, Lithuania and Bulgaria with modest patent and publication outputs.

Figure 1. Patents vs. Citable documents by R&D personnel. Annual average 2008-2010



Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

The choice of number of publications as an indicator of representative output of HEIs' research activity (and therefore excluding patents) is more problematic if there are considerable differences in specialisations across the university systems in different countries. Some universities systems may specialise in the social sciences and humanities field of science (FOS) the main output of which are publications, and where patents are practically nonexistent. Others, by contrast, specialise in technical FOS with a much higher tendency to patent.

The problem we pose is whether or not the activity of publishing implies that patenting is relinquished and vice versa; in other words, whether the two outputs are positively correlated.

Some authors consider that patenting supplants scientific publishing, that is, that patenting implies that publishing is relinquished and vice versa. This is what some authors call the "substitution effect" (Klitkou and Gulbrandsen, 2010). The explanation may be that the patenting process often involves a delay in publication, making it more difficult to publish a scientific paper. Klitkou and Gulbrandsen (2010) also argue that the researcher's attention might have moved on to other problems, it may be intellectually or psychologically challenging to start work on a delayed paper, etc. In turn, Crespi *et al.* (2011) state that if academic inventors become too involved in patenting activity, they may become distracted from (or devote less time to) other activities and focus mainly on the production of new knowledge that is patentable and from which some financial return can be extracted. Finally, Klitkou and Gulbrandsen (2010) assert that the patenting process also involves some degree of secrecy.[7]

On the other hand there are authors who consider that a "reinforcement effect" (Klitkou and Gulbrandsen 2010) takes place between the two research activities of publishing and patenting, in other words, a situation in which research activity generates patents that translate into publications and/or publications that generate patents. This may occur in any direction since patenting can open up new scientific opportunities, lead to new ideas, create scientific networks, etc. And, alternatively, patents may result from these opportunities and networks.

Most of the empirical evidence supports the theory of the "reinforcement effect" suggesting that when a university produces one of the outputs (patents or publications), it may be likely to produce the other output as well.[8] Carayol (2007) and Breschi et al. (2007) find a strong and positive relationship between patenting and publishing. Crespi et al. (2011) show that (the intensity of) academic patenting complements publishing up to a certain level of patenting output, after which they find evidence of a substitution effect.

When analysing universities' research output, the existence of various research outputs and the selection of merely one of them (e.g. publications) would not constitute an important problem if there were a positive relationship between the two activities (publishing and patenting) that mutually reinforced them.

Figure 2 shows that the two leading research outputs have kept pace over the last decade for the HEIs of the EU-28. Patents have multiplied by 1.84 and publications by 1.89. This

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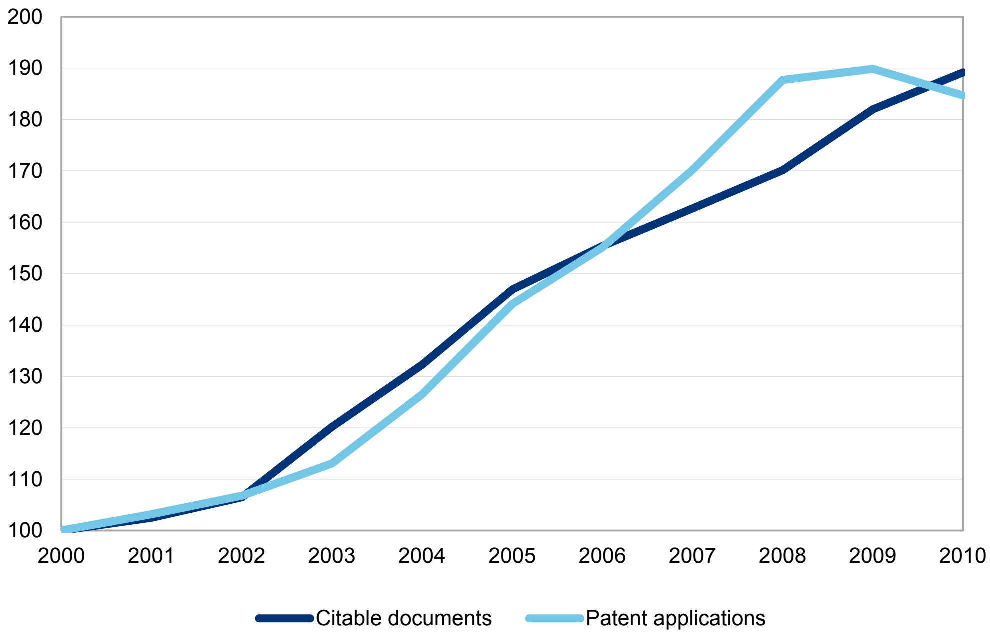
[7] Klitkou and Gulbrandsen (2010) state that in interviews, some academic inventors claim they cannot talk about their most recent research because the relevant patents have not yet been secured.

[8] A more detailed discussion about the complementarity or substitutability of publishing and patenting and their determinants is to be found in Salas (2012) and Crespi *et al.* (2011).

fact indicates that there are no significant changes in the relative composition of the research output of EU-28 HEIs.

Figure 2. Evolution of scientific output and patent applications. EU-28. 2000-2010
2000=100



Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

In summary, both the evidence found in other countries (Klitkou and Gulbrandsen 2010; Carayol 2007 and Breschi *et al.* 2007) and the similar evolution of patents and documents in **figure 2** indicate that the substitution effect does not exist, but rather there is a reinforcement effect between the activities of publishing and patenting. It therefore seems a fairly reasonable approach to use only the number of publications as a representative indicator of the volume of research output from European universities.

3. DATA

The data correspond to 28 European university systems for the period 2008 to 2012. As a measure of output we use the number of citable documents by country and by field of science. There are two main databases that provide information on the research output: The Web of Science (WoS) and SCIMAGO (Scopus).[9]

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[9] Another database is Google Scholar, launched in 2004. It is a search engine specialising in scientific literature. It offers a free search area within a corpus of articles and books that is constantly expanding and has a wide coverage. Various studies have compared Google Scholar with the Web

The WoS database, produced by Thomson Reuters, includes more than 12,000 international journals and is managed commercially by the International Scientific Institute (ISI). This database, initially entitled Current Contents (CC), became the source of the Science Citation Index, which performs its extractions from the scientific journals indexed in the CC. Although it compiles information from 23 million documents and 3,300 publishers from 71 countries, it is predominated by journals in English and journals in the *hard* sciences. As a result publications written in languages other than English or in other fields of knowledge such as the social sciences are underrepresented.

The other database is Scopus, established by the Elsevier group in 2004. It has indexed articles from approximately 22,000 journals and 55 million documents since 1996. Nowadays, Scopus is the most serious competitor to the WoS. The geographical source of the titles of scientific journals is varied: it covers information from journals in 97 countries and English language journals are not overrepresented since 60% are not based in the United States (US). It has many more social science titles, but covers a limited period of eleven years (Kosmopoulos and Pumain 2007). This database is a serious alternative to the well-established Web of Science database, mainly because it is open access, it has a larger range of sources,[10] it includes journals in languages other than English and it assesses the quality of citations (Falagas *et al.* 2008); it is increasingly used by researchers.[11]

The SCImago Research Group[12] developed the SCImago Journal & Country Rank (SJR) from the widely known algorithm Google PageRank™, a portal that includes the journal and country scientific indicators developed from the information contained in the Scopus database from 1996 onwards. Although this database does not offer information for the specific university sector, it includes information about the quantity and quality of research.

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of Science or with Scopus, concluding that Google Scholar allows scholars to take into account a much more significant amount of scientific work by a given author, in particular because it includes proceedings and papers from conferences, theses, monographs and book chapters (Harzing and van der Val 2008).

[10] The Scopus database contains a larger number of journals and covers the humanities. It has twice the number of journals indexed than the WoS, which ensures a greater thematic and geographical coverage. Corera *et al.* (2010)

[11] For example, Moed *et al.* (2011) analyse relationships between university research performance and concentration using the SCImago database. They find that that a larger publication output is associated with a higher citation impact.

[12] SCImago is a Spanish research group constituted by the High Council for Scientific Research (Consejo Superior de Investigaciones Científicas [CSIC]) and the Universities of Granada, Extremadura, Carlos III (Madrid) and Alcalá de Henares; it is dedicated to information analysis, representation and retrieval by means of visualisation techniques.

Table 1. Scopus vs. Web of Science

	SCIMAGO (Scopus)	WEB OF SCIENCE (WoS)
Source database	Scopus (Elsevier B.V)	Inst. for Scientific Information
Indexed documents	55 million	23 million
Number of journals	22,000	12,000
Publishers	5,000	3,300
Countries of journals	97	71
Categories	304	220
Access	Open	Restricted

In summary, from the comparison of the two databases in **table 1** we see that Scopus includes more documents, more journals, more scientific categories and has a wider geographical coverage than Web of Science. Researchers can freely access the following research output information by country and year: number of documents, number of citable documents, number of citations, citations per document, etc.[13] The information is also disaggregated by research area. This disaggregation is necessary in our study because of our aim to analyse the differences in researcher output controlling for specialisation. To this end we created a correspondence between the research areas used by publications (SCIMAGO) and the fields of science (FOS) used by Eurostat for both patents and for R&D expenditure and personnel (table 2).

[13] The information is available on the following website: http://www.scimagojr.com/countryrank.php

Table 2. Correspondence between Research Areas (SCIMAGO) and Fields of science (FOS)

Fields of science (FOS) (Eurostat))		Research Areas (SCIMAGO)
FOS 1	Natural Science	Chemistry
		Computer Science
		Earth and Planetary Sciences
		Mathematics
		Physics and Astronomy
		Environmental Science (except Env. engineering)
FOS 2	Engineering and technology	Chemical Engineering
		Energy
		Engineering
		Materials Science
		Environmental engineering
FOS 3	Medical and health sciences	Dentistry
		Health Professions
		Medicine
		Nursing
		Biochemistry, Genetics and Molecular Biology
		Immunology and Microbiology
		Neuroscience
		Pharmacology, Toxicology and Pharmaceutics
FOS 4	Agricultural sciences	Veterinary
		Agricultural and Biological Sciences
FOS 5	Social sciences	Business, Management and Accounting
		Decision Sciences
		Economics, Econometrics and Finance
		Psychology
		Social Sciences
FOS 6	Humanities	Arts and Humanities

Source: Own elaboration.

Table 3 presents the information for the average of the period 2008-12 for each of the EU-28 countries. The country with the highest scientific output is the UK (157,501 citable documents, representing 17.4% of total EU output, followed by Germany (150,652 documents), France (111,261 documents), Italy (87,515 documents) and Spain (79,255 documents).

In terms of quality, measured by the number of citations per document, the countries with the highest quality production are Denmark, Netherlands, Sweden, Belgium, Ireland, Finland, Austria or UK, all of which have more than 5 citations per citable document. At the opposite extreme are Romania and Lithuania with fewer than 2 citations per document.

Table 3. Research indicators by country. Annual average 2008-2012

Country	**R&D expenditure in Higher Education and Government sector** (million euros)	**R&D personnel in Higher Education and Government sector** (full-time equivalent)	**Citable documents**	**Non-self citations**	**Non-self citations per citable documents**
Austria	2,485.3	18,459	19,758	105,568	5.34
Belgium	2,382.9	26,670	28,715	167,494	5.83
Bulgaria	108.9	14,181	3,845	10,992	2.86
Croatia	202.8	8,071	5,942	13,505	2.27
Cyprus	57.3	831	1,457	5,635	3.87
Czech Rep.	993.0	25,597	16,813	50,253	2.99
Denmark	2,276.6	19,557	19,458	124,965	6.42
Estonia	125.5	3,413	2,170	9,391	4.33
Finland	2,015.7	23,831	16,817	90,373	5.37
France	15,541.3	157,681	111,261	475,934	4.28
Germany	22,961.0	209,269	150,652	660,904	4.39
Greece	948.2	28,857	18,551	80,687	4.35
Hungary	439.5	16,318	10,116	38,691	3.82
Ireland	829.2	7,633	11,514	63,044	5.48
Italy	8,373.1	108,901	87,515	392,411	4.48
Latvia	88.7	4,666	1,009	2,228	2.21
Lithuania	189.4	8,679	3,254	6,375	1.96
Luxembourg	165.9	1,626	1,060	4,594	4.33
Malta	16.2	377	294	980	3.33
Netherlands	5,411.3	44,963	50,234	319,673	6.36
Poland	1,803.5	63,037	34,967	79,260	2.27
Portugal	1,120.4	28,146	17,308	66,256	3.83
Romania	411.2	18,736	12,732	18,510	1.45
Slovakia	245.6	14,027	5,313	14,469	2.72
Slovenia	229.6	5,595	5,604	19,092	3.41
Spain	6,736.0	123,937	79,255	309,543	3.91
Sweden	3,648.5	19,757	31,877	189,255	5.94
UK	11,196.6	188,309	157,501	787,324	5.00
UE-28	**91,003.4**	**1,191,125**	**904,993**	**4,107,406**	**4.54**

Source: SCImago Journal Country Rank, Eurostat and own elaboration.

4. THE FACTS

The term "knowledge-based economy" stems from the wide recognition of the place of knowledge and technology in modern economies. These societies are characterised by their intensive use of knowledge not only in practically every sphere of daily life but also in production activities. Practically all their activities are based on knowledge and on knowledge management. There is no question now that knowledge is the main driver of increased productivity and economic growth in advanced societies.

In European countries HEIs play a key role in this area. In universities knowledge is created through R&D activities, disseminated through their teaching activities and the publication of their research results, most of the time with guaranteed free access, and transferred by means of collaboration agreements with companies.

Universities are key actors in the knowledge society and are essential for achieving greater levels of sustainable well-being. An extensive literature demonstrates the importance of universities in the socio-economic development of their economies.[14] Governments, aware of these benefits, devote considerable resources to their public universities. Precisely for this reason they demand a better use of these resources and more and better results in all their activities, but especially in R&D. The empirical evidence shows that universities in some countries have better R&D results than others, even when they use fewer resources. Before going on to explore the causes of this varied performance across European countries, we first consider it useful to review some of the typical features of research activity in their university systems.

We begin by analysing the importance of universities in research activity. Eurostat considers four large sectors of execution in expenditure on R&D activities: Higher Education, Government, Business enterprise sector and Private non-profit sector. **Figure 3** shows that the HEIs of the EU-28 account for almost a quarter of R&D expenditure (23.4%) and are, following companies (63.5%), the second most important agent in R&D activities. In some countries HEIs account for more than half the total amount of financial resources devoted to R&D. This is the case of Cyprus or Lithuania, where expenditure on R&D in HEIs represents 57.3% and 54.7% of total R&D expenditure, respectively.

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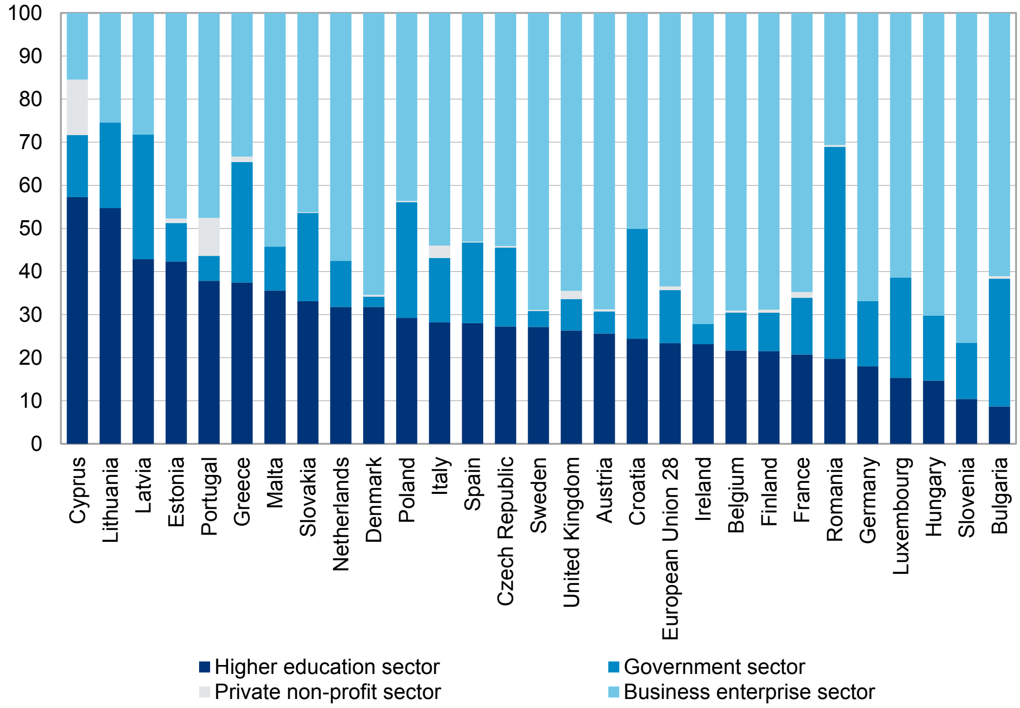
[14] The positive impacts of universities on the economic growth of their countries' economies have been widely demonstrated in the literature, especially in the case of North American universities (Pastor, Pérez and Ferández, 2013).

Figure 3. Distribution of R&D expenditure by sectors of performance. EU-28 countries. 2013

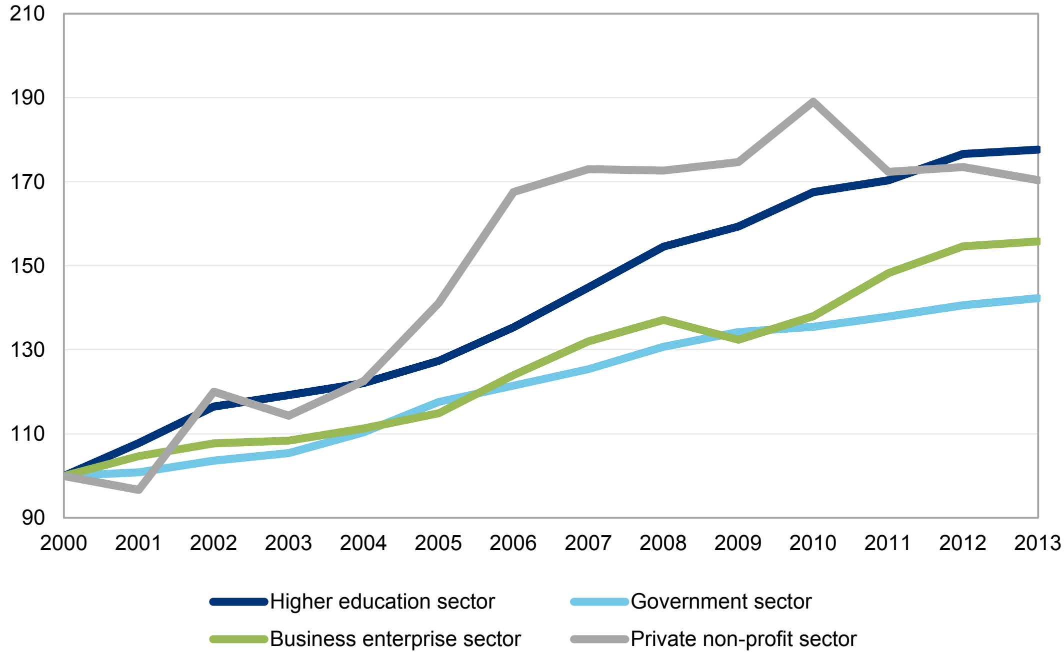
Percentages



Source: Eurostat.

Figure 4 shows the evolution of R&D expenditure by sectors. The figure reports the spectacular growth of R&D expenditure in all sectors, but especially in HEIs. Over the period considered, HEIs have increased their expenditure by 77.6% compared to the average of 58% for all sectors, 55.8% for the business enterprise sector or 42.3% for the government sector. This increase in R&D expenditure in the EU-28 as a whole obscures some particularly significant cases, such as the Czech Republic, Estonia, Cyprus, Romania, Lithuania or Slovakia, whose R&D expenditure in the HEI sector witnessed growth of over 600% from 2000 to 2013.

Figure 4. Evolution of R&D expenditure by sector of performance. EU-28. 2000-2013. 2000=100



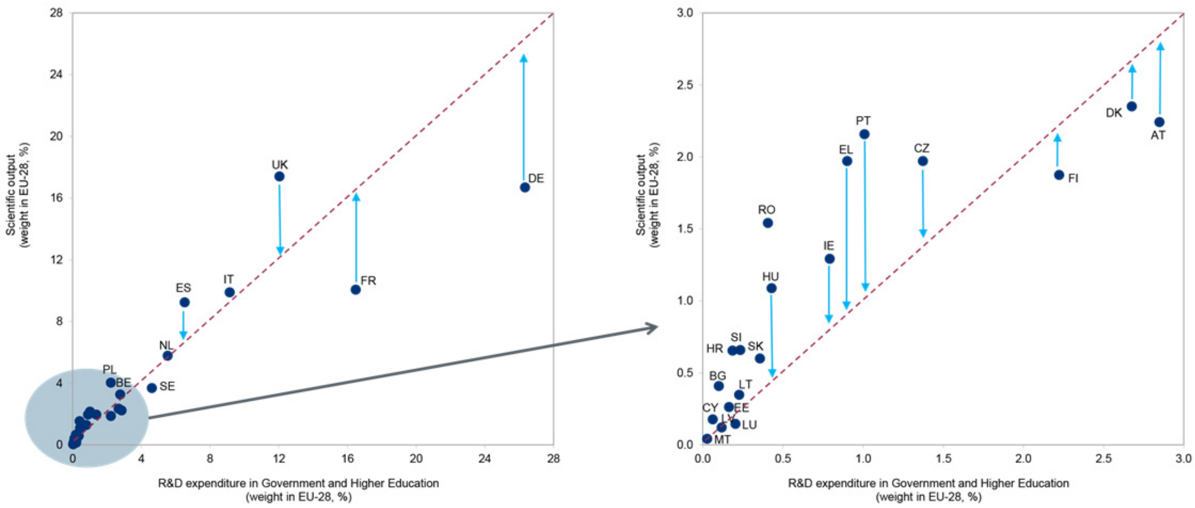
Source: Eurostat.

Obviously, the more resources devoted to research in universities, the greater the research output will be. **Figure 5** shows the relationship between the resources in public R&D agents (universities, public research centres and hospitals) and one of the most important research outputs: the number of publications. Note that the EU countries with the greatest weight in terms of R&D expenditure by HEI also have the greatest weight in terms of publications. This relationship is positive and statistically significant.

However, **figure 5** also reveals a very important fact: research output does not depend exclusively on the resources used. Some countries are getting more value for the money allocated to R&D than others. That is the case of some small countries like Bulgaria, Romania, Croatia, Cyprus, Slovenia, Hungary, Greece and Portugal. The weight of these countries in terms of publications is more than twice their weights in terms of R&D expenditure. On the opposite side are the largest EU countries, Germany and France, where the weight in terms of R&D expenditure is higher than in terms of publications.[15]

[15] With the only exception of UK and Spain, whose weights in terms of publications are higher than in terms of R&D expenditure. In the case of the UK the weight in terms of publications is 44% higher than the weight in terms of R&D expenditure, whereas in the case of Spain it is 42% higher.

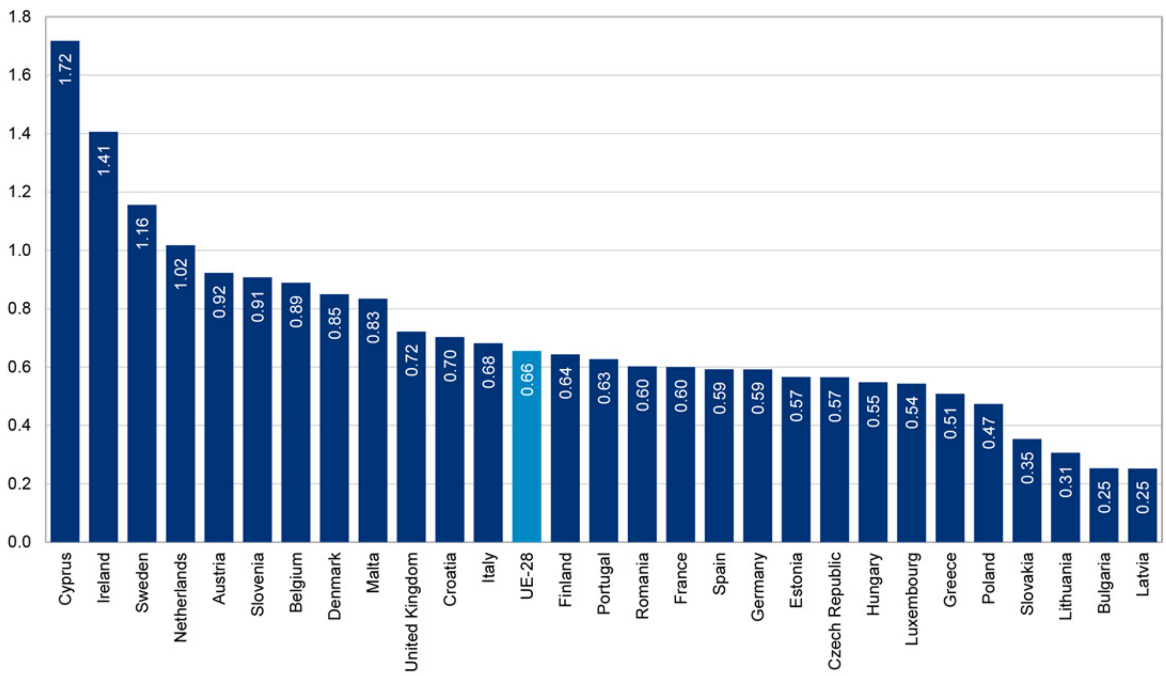
Figure 5. Scientific output vs. R&D expenditure. EU countries. 2012



This same circumstance can also be observed by analysing the differences in scientific output per capita. **Figure 6** shows the scientific output related to R&D personnel in Government and Higher Education. As can be seen from the figure, there are important differences in output per capita among the EU countries. (i.e., the scientific output per capita in Cyprus is 6.8 times that of Latvia).

Figure 6. Scientific output related to R&D personnel. EU countries. 2012

Citable documents per R&D personnel

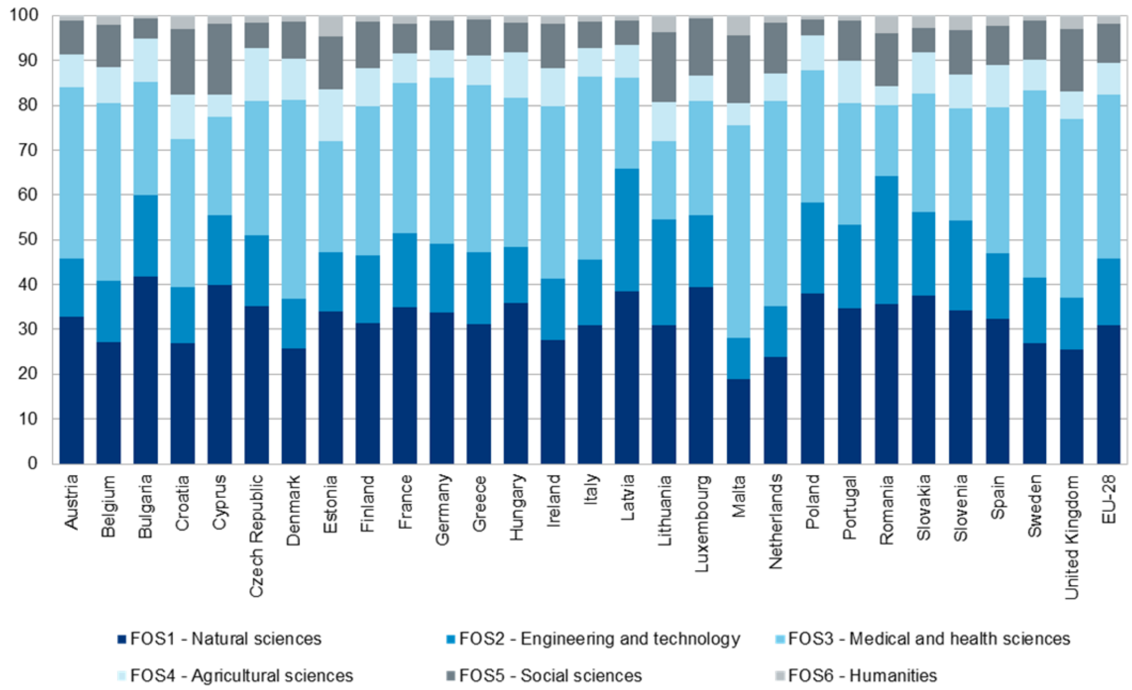


Source: SCImago Journal & Country Rank and Eurostat.

The next question we analyse is whether there are differences in the specialisations of European university systems. **Figure 7** reveals important differences in specialisation in the fields of science (FOS). For example, the specialisation of Estonia in Humanities is 2.6

times the EU average and 8 times that of Luxembourg. Similarly, UK is overspecialised in Social Sciences and Humanities: its specialisation in Social Sciences is 60% higher than the EU average and in Humanities, 70% higher than the EU average. In contrast, Germany is under? less? specialised in Humanities: 40% lower than the EU average. The Netherlands and the Nordic countries (Sweden and Denmark) show a strong specialisation in Medical and Health Sciences.

Figure 7. Distribution of scientific output by field of science. EU countries. 2012
Percentage



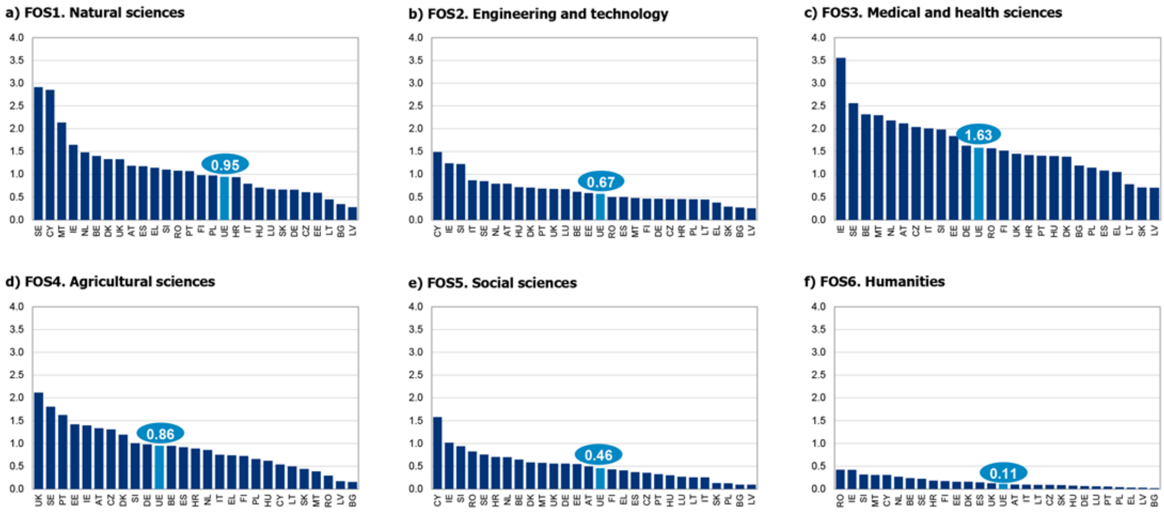
Source: SCImago Journal & Country Rank and own elaboration.

Any differences in specialisations in the university systems will only explain the differences in output per capita among the HEIs in European countries if there are also different outputs per capita between the various FOS. **Figure 8** represents the number of citable documents per R&D personnel. It reveals important differences in productivity among the FOS. The productivity of FOS3 (Medical sciences) is 1.58 citable documents per R&D personnel, 14 times higher than FOS6 (Humanities). Similarly, the productivity of FOS1 (Natural sciences) is 0.95 citable documents per R&D personnel, 8.4 times higher than FOS6.

As well as the FOS specialisation, another of the reasons that may explain the differences in per capita output in EU countries' HEIs is the difference in per capita resources. Countries whose researchers have more resources for research activity will obtain greater output.

Figure 8. Scientific output related to R&D personnel by field of science. EU countries. 2012

Citable documents per R&D personnel



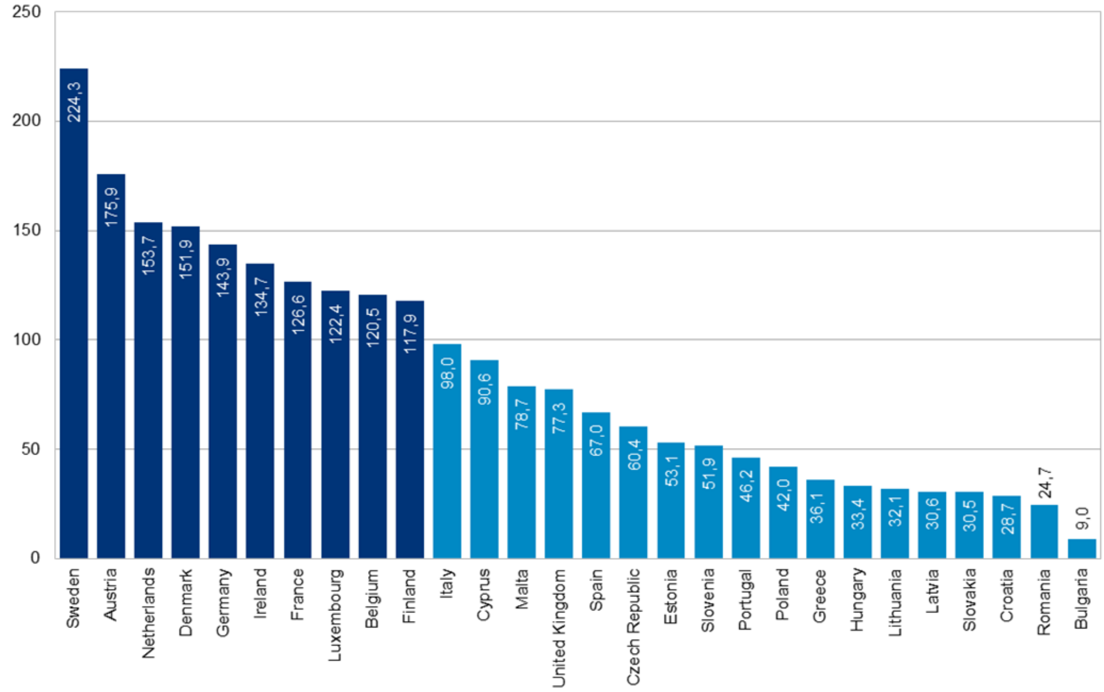
Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

Figure 9 represents the R&D expenditure per R&D personnel and reveals important differences in R&D expenditure per capita. Note, for example, that the R&D per capita in Sweden is 2.2 times higher than the EU average and 25 times higher than in Bulgaria. In general one group of countries allocates far more resources than the average: Sweden, Austria, Netherlands, Denmark and Germany. The R&D per capita of these countries is more than 40% higher than the EU average. In contrast, in countries like Bulgaria, Romania, Croatia, Slovakia, Latvia, Lithuania, Hungary, Greece, Poland, Portugal, Slovenia and Estonia the R&D per capita is 40% lower than the average.

In summary, we find considerable differences in output per capita (citable documents per R&D researcher) among the HEIs of EU countries. The evidence indicates that there are four possible factors causing these differences among the HEIs of the EU countries: differences in field of science specialisation, differences in output per capita within FOS, differences of quality and differences in R&D expenditure per capita.

We will analyse the extent to which differences in terms of specialisation, efficiency within the scientific fields, quality of the output and R&D expenditure per capita explain the differences in the research output among HEIs in the EU.

Figure 9. R&D expenditure per R&D personnel. EU countries. 2012
EU-28=100



Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

5. METHODOLOGY

We need a methodology that identifies the determinants of HEI research output. Specifically, we want to know to how far differences in terms of intangible investments (R&D expenditure), output quality, field of science specialisation and inefficiencies explain the differences in the research output and productivity among the EU HEIs.

To this end we adapt the multi-step approach developed in Maudos, Pastor and Serrano (2000) which is based on a DEA non-parametric methodology. This step by step DEA-based methodology allows us to decompose total inefficiency into the composition (or specialisation) effect and the effect due to inefficiency within each sector.

These authors applied that approach to Spanish regions and output by industry; in this case we will apply it to EU countries and research output by HEIs and field of science. We also adapt the methodology to take into account not only the quantity of research but also output quality following a 5-step methodology.

This will allow us to analyse the universities' research output in terms of differences in the output quality within each specific FOS, differences in intra-field inefficiency (inefficiencies of the HEIs within each specific field), and differences in specialisation (inefficiencies of the HEIs due to their FOS specialisation).

The usefulness of this approach is that it allows us to incorporate the particular nature of HEI research activity into the analysis. We are able to consider that the FOS may be characterised by different propensities to publish and to cite as the data suggest (Figure 8). These differences in the characteristics of the FOS may influence the aggregated results. For this reason, instead of directly considering the aggregate research output of the HEIs, we consider the output of each FOS. From this standpoint the approach allows us to distinguish two different types of inefficiency: an inefficiency of composition due to specialisation and another type of inefficiency that we will call intra-field inefficiency, which is associated with a deficient use of resources allocated to each particular FOS. In order to properly measure the maximum achievable output of the HEIs in each country, and their global inefficiency, the analysis should include both sources of inefficiency: composition and intra-field.

A breakdown such as this enables two components of efficiency to be distinguished. *Intra-field* efficiency, due to a more or less efficient use of productive factors within each FOS, and *composition* efficiency which depends on being specialised in the FOS that are more or less productive. According to this second component, the HEIs of a country can improve their efficiency simply by increasing the weight of the FOS that tend to be more productive.

In order to illustrate our 5-step methodology let us assume that there are *R* countries and *N* fields of science (FOS), and that ($X^n{}_{i1}$,..., $X^n{}_{iM}$) is the vector of *M* inputs that the HEIs of country *i* use in FOS *n* for the production of Y_i^n .

STEP 1: Research output quantitative inefficiency by scientific field

First we consider efficiency in terms of number of documents by FOS to evaluate by how much each country could increase the number of documents in each FOS without using more resources and personnel. The research output quantitative inefficiency of the HEIs of country *i* in FOS *n* (θ_i^n) will be obtained by the following standard DEA problem:

$$Max\ \theta_i^n \tag{1}$$

s.t.

$$\sum_{r=1}^{R} \lambda_r Y_r^n \geq Y_i^n \theta_i^n$$

$$\sum_{r=1}^{R} \lambda_r X_{rm}^n \leq X_{im}^n \quad m = 1, \dots, M$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

$\boldsymbol{\theta_i^n}$ is the efficiency score of the HEIs of country *i* in the scientific field *n*, and represents the potential increase that the HEIs of country *i* could achieve in their output in scientific field *n* without increasing the input vector (in our case R&D expenditure and R&D personnel). A higher score implies more inefficiency and a value of 1, the minimum value, means that country *i* is efficient in field *n*, as it is at the frontier.

Using this efficiency score of HEI of country *i* in each of the six fields of science considered, ($\boldsymbol{\theta_i^n}$) we are able to calculate the potential output of the countries in each FOS ($\boldsymbol{\hat{Y}_i^n}$), that is, the maximum output that the countries' HEIs could achieve in each FOS if they were efficient in each one of their *n* FOS.

$$\hat{Y}_i^n = Y_i^n \, \theta_i^n \tag{2}$$

STEP 2: Research output inefficiency by scientific field including the quality of the output (pure inefficiency)

The previous research output inefficiency of HEI of country *i* in FOS *n* (ϑ_i^n) does not consider the quality of the output. However, failing to consider quality would imply penalising those HEI that consume more inputs not because they are more inefficient, but because the output they produce is of a higher quality. If this aspect is not taken into account, we would be interpreting as inefficiency what is actually a higher consumption of resources to produce a higher quality output.

The indicators most commonly used by researchers in order to take into account of the quality of research are: the number of citations per document, the impact factor (IF), the percentage of publications in journals in the first quartile (Q1), the SCImago Journal Rank (SJR), the Eigenfactor score, the h-index and the $^{n}h_3$ index[16]. All these indicators are based on the analysis of the citations received by documents and all of them attempt, via a normalisation technique, to improve information on the number of citations, to compensate for the variability of the citation culture in different fields (Center for Science and Technology Studies [CWTS]; SCImago; Vieira *et al.* 2009).

The use of citations as an indicator of research quality and impact is based on the assumption that the citation of a document represents recognition of its interest and usefulness in the construction of new knowledge (González-Albo 2012).[17] Although citation-

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[16] See Pastor, Serrano and Zaera (2014).

[17] A positive correlation between peer judgements and different citation-based indicators has been found (Rinia *et al.* 1998). Charlton and Andras (2007) suggest using the total citations of universities as a measure of output. According to these authors, this indicator has certain advantages over other indicators: it is cheap, quick, simple, transparent, objective, replicable and permits international and longitudinal comparisons.

based indicators have certain limitations, widely described in the literature (Rey 2009; Moed 2005), their use is currently accepted as indicators of research influence.

We use the number of citations per document (CD) as an indicator of scientific output quality.

The research output inefficiency of HEIs of country *i* in FOS *n* that controls for the quality of output (θ_{Qi}^{n}) will be obtained by including an additional restriction to the problem of STEP 1.

$$Max\ \theta_{Qi}^{n} \tag{3}$$

s.t. And

$$\sum_{r=1}^{R} \lambda_r Y_r^n \geq Y_i^n \theta_{Qi}^n$$

$$\sum_{r=1}^{R} \lambda_r X_{rm}^n \leq X_{im}^n \quad m = 1, \dots, M$$

$$\sum_{r=1}^{R} \lambda_r CD_r^n \geq CD_i^n$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

where θ_{Qi}^{n} is the efficiency score of HEIs of country *i* in the scientific field *n* that controls for the quality, and represents the potential increase that HEIs of country *i* could achieve in the output of the scientific field *n* without increasing the input vector and maintaining the same quality of the production research (citations per document).

As in STEP 1 we can calculate the potential output of each field of science *n* controlling for quality ($\boldsymbol{\hat{Y}_{Qi}^{n}}$), in other words, the maximum output that could be achieved in each FOS if the HEIs of each country *i* were efficient, controlling for quality. To do this we use the efficiency score of HEIs of country *i* in the scientific field *n* that controls for quality ($\boldsymbol{\theta_{Qi}^{n}}$)

$$\hat{Y}_{Qi}^{n} = Y_i^n \, \theta_{Qi}^{n} \tag{4}$$

STEP 3: Scientific field efficient aggregate output

Using the results of STEP 1 and STEP 2, we can estimate the efficient aggregate output of the HEIs of each country (i.e., the aggregated output assuming that all the HEIs are efficient in each scientific field). We will calculate both the aggregated output in terms of the number of documents ($\boldsymbol{\widehat{Y}_i}$) and the aggregate output controlling for quality ($\boldsymbol{\widehat{Y}_{Qi}}$)

$$\widehat{Y}_i = \sum_{n=1}^{N} \widehat{Y}_i^n = \sum_{n=1}^{N} Y_i^n \, \theta_i^n \tag{5}$$

$$\widehat{Y}_{Qi} = \sum_{n=1}^{N} \widehat{Y}_{Qi}^n = \sum_{n=1}^{N} Y_i^n \, \theta_{Qi}^n \tag{6}$$

However, being efficient in each scientific field does not guarantee being efficient in aggregated scientific output, since there is still another type of inefficiency associated with the field of science composition of production. In other words, being efficient in aggregate production necessarily implies being efficient in each FOS (i.e., intra-field efficiency), but also having a good FOS specialisation (i.e., composition efficiency).

STEP 4: Composition inefficiency

In this step we estimate the composition inefficiency (θ_i^{CE}), the inefficiency that would exist even with no technical inefficiency within any scientific field

$$Max\ \theta_i^{CE} \tag{7}$$

s.t.

$$\sum_{r=1}^{R} \lambda_r \, \widehat{Y}_r \geq \widehat{Y}_i \theta_i^{CE}$$

$$\sum_{r=1}^{R} \lambda_r \, X_{rm} \leq X_{im} \quad m = 1, \dots, M$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

θ_i^{CE} is the efficiency score of HEIs of country *i* and represents the potential increase that the HEIs of country *i* could achieve in their aggregate output without increasing the input vector and assuming that they are also achieving the maximum output (given the quantity of inputs) in each scientific field. Therefore, this composition inefficiency term captures the inefficiency associated with the particular scientific composition/specialisation of the HEIs of each country.

From the results of STEP 3 we can calculate both the aggregated potential output of the HEIs of each country without adjusting for quality ($\widehat{\boldsymbol{Y}}_{\boldsymbol{i}}^{*}$) and the potential output controlling for quality ($\widehat{\boldsymbol{Y}}_{\boldsymbol{Qi}}^{*}$)**.** That is, the maximum aggregated output that each country *i* could achieve without using more inputs if their HEIs had a suitable composition (specialisation by scientific fields).

$$\hat{Y}_i^* = \hat{Y}_i \, \theta_i^{CE} \tag{8}$$

$$\hat{Y}_{Qi}^* = \hat{Y}_{Qi} \, \theta_{Qi}^{CE} \tag{9}$$

STEP 5: Global research output inefficiency

The global research inefficiency score in terms of quantity of documents without adjusting by quality is (ϑ_i). It can be obtained as the ratio between the maximum attainable output $\hat{Y}_i^*$and the actual output Y_i:

$$\theta_i = \frac{\hat{Y}_i \theta_i^{CE}}{Y_i} = \frac{\hat{Y}_i^*}{Y_i} \tag{10}$$

or by solving the following problem:

$$Max\ \theta_i \tag{11}$$

s.t.

$$\sum_{r=1}^{R} \lambda_r \, \hat{Y}_r \geq \hat{Y}_i \theta_i$$

$$\sum_{r=1}^{R} \lambda_r \, X_{rm} \leq X_{im} \quad m = 1, \dots, M$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

Note that part of the potential improvement in terms of number of documents shown by this score might be associated with a decrease in their quality.

We can express this **global quantitative inefficiency** score (ϑ_i) as the product of two factors:

$$\theta_i = \frac{\hat{Y}_i^*}{Y_i} = \frac{\hat{Y}_i^*}{\hat{Y}_{Qi}^*} \cdot \frac{\hat{Y}_{Qi}^*}{Y_i} = QE_i \cdot \theta_i^{PE} \tag{12}$$

The first factor is the **quality effect (**$QE_i = \hat{Y}_i^* / \hat{Y}_{Qi}^*$) and represents the quality bias in the global quantitative inefficiency indicator due to considering only the quantity of documents and not their quality. If $QE_i < 1$, it means that the quantitative indicator is penalising that country because it has a higher quality output that is not taken into account. The second factor is the **global pure inefficiency** score (θ_i^{PE}). This indicator, when controlled for quality, is a more suitable indicator of efficiency because it measures how much the scientific output of the HEIs in each country can increase without raising inputs or reducing quality.

In turn, we can decompose the **global pure inefficiency** score into two additional components according to the following expression:

$$\theta_i = \frac{\hat{Y}_i^*}{Y_i} = \frac{\hat{Y}_i^*}{\hat{Y}_{Qi}^*} \cdot \frac{\hat{Y}_{Qi}^*}{Y_i} = \frac{\hat{Y}_i^*}{\hat{Y}_{Qi}^*} \cdot \frac{\hat{Y}_{Qi}^*}{\hat{Y}_{Qi}} \cdot \frac{\hat{Y}_{Qi}}{Y_i} = QE_i \cdot \theta_i^{PE} = QE_i \cdot \theta_i^{CE} \cdot \theta_i^{IE} \tag{13}$$

The first component, the **composition inefficiency** (ϑ_i^{CE}), represents the inefficiency due to the field of science composition/specialisation. The second factor is the **intra-field inefficiency** (ϑ_i^{IE}) and indicates the aggregate intra-field inefficiency.

6. RESULTS

Table 4 presents the results of the different indicators. Column 1 shows the results of the global quantitative inefficiency score. On average, given the actual use of inputs and without taking into account quality, the research output of the HEI in the EU could increase by around 20% if the inefficiencies were removed.

In some countries output could be increased by a factor of 2 or more (Latvia, Luxembourg, Lithuania, Malta, Slovakia). United Kingdom is the only efficient country, the only one whose HEIs produce the maximum number of publications given the inputs used. In the group of most efficient countries (low inefficiency scores) are Sweden (1.01) and Germany (1.05).

But the most suitable indicator to measure the countries' real degree of efficiency is the indicator that also controls for quality of scientific output. The second column presents the quality effect and the third, the results of efficiency controlled for quality. The results indicate that output could increase to 18% for the EU countries as a whole and if all inefficiencies were removed. Control for quality does not significantly alter the results in most countries. As can be seen, the quality effect is very limited except in cases like the Netherlands and Denmark, where control for quality significantly improves their performances.

Columns 4 and 5 show the two components of that global inefficiency. Most of the inefficiency comes from inefficiencies within each specific field. The inefficiency associated with the composition is much less significant.

Hence, for the EU-27 as a whole, composition inefficiency is only 2.2%, whereas intra-field inefficiency is 15.4%. In other words, composition inefficiencies represent a mere 12.3% of global pure inefficiency while intra-field inefficiencies represent the remaining 87.6%.

Table 4. Global inefficiency and its components

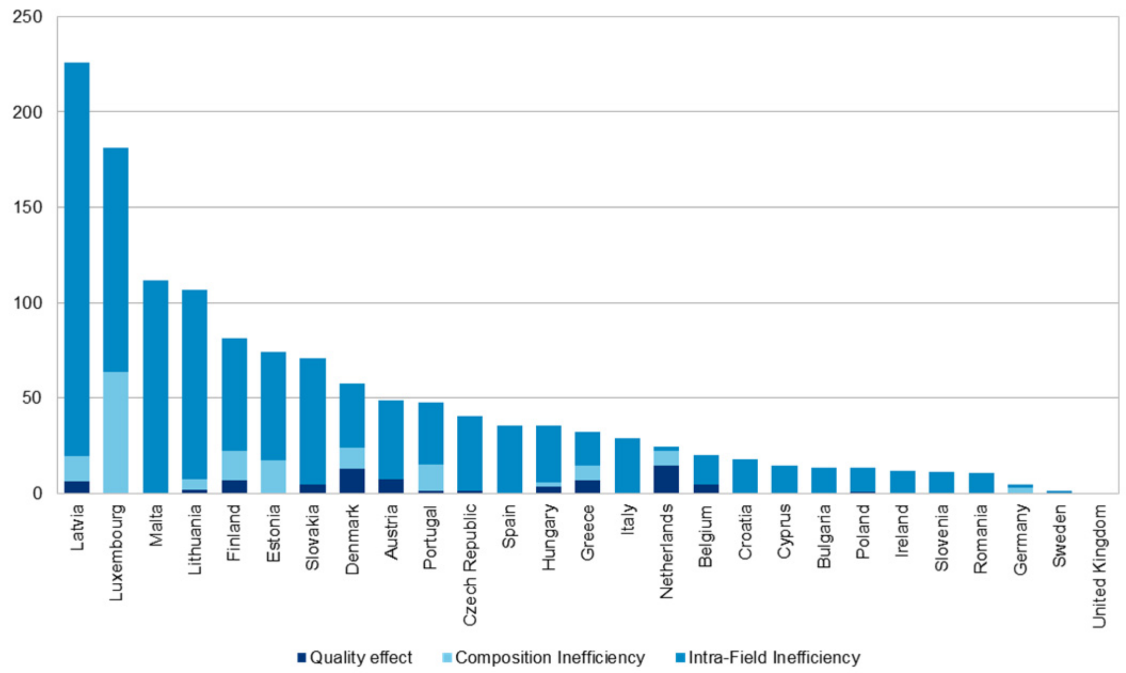
			Decomposition of Global pure inefficiency		
	Global quantitative inefficiency $(\theta_i = \hat{Y}_i^*/Y_i)$	**Quality effect** $(QE_i = \hat{Y}_i^*/\hat{Y}_{Qi}^*$	**Global pure inefficiency** $(\theta_i^{PE} = \hat{Y}_{Qi}^*/Y_i$	**Composition inefficiency** $(\theta_i^{CE} = \hat{Y}_{Qi}^*/\hat{Y}_{Qi}$	**Intra-field inefficiency** $(\theta_i^{IE} = \hat{Y}_{Qi}/Y_i$
Belgium	1.20	1.04	1.15	1.00	1.15
Bulgaria	1.14	1.00	1.13	1.00	1.13
Czech Rep.	1.40	1.01	1.39	1.00	1.39
Denmark	1.57	1.11	1.42	1.09	1.30
Germany	1.05	1.00	1.05	1.03	1.02
Estonia	1.74	1.00	1.75	1.14	1.53
Ireland	1.11	1.00	1.11	1.00	1.11
Greece	1.32	1.06	1.25	1.07	1.16
Spain	1.35	1.00	1.35	1.00	1.35
Croatia	1.18	1.00	1.18	1.00	1.18
Italy	1.29	1.00	1.29	1.00	1.29
Cyprus	1.15	1.00	1.15	1.00	1.15
Latvia	3.26	1.03	3.15	1.07	2.95
Lithuania	2.06	1.01	2.04	1.04	1.96
Luxembourg	2.81	1.00	2.81	1.44	1.95
Hungary	1.35	1.03	1.32	1.02	1.29
Malta	2.12	1.00	2.12	1.00	2.12
Netherlands	1.25	1.14	1.09	1.07	1.02
Austria	1.49	1.06	1.40	1.00	1.40
Poland	1.13	1.01	1.13	1.00	1.13
Portugal	1.48	1.01	1.46	1.12	1.31
Romania	1.11	1.00	1.11	1.00	1.11
Slovenia	1.11	1.00	1.11	1.00	1.11
Slovakia	1.71	1.04	1.65	1.00	1.65
Finland	1.81	1.05	1.73	1.12	1.54
Sweden	1.01	1.00	1.01	1.00	1.01
U.K.	1.00	1.00	1.00	1.00	1.00
Weighted average	**1.20**	**1.02**	**1.18**	**1.02**	**1.15**

Figure 10 represents the magnitude of global quantitative inefficiency across EU countries, namely, the percentage increase of the research output of each country's HEI, and its sources. According to these results Latvia is the most inefficient country. Its research output could be increased by 225.9%. In contrast, the UK is the most efficient country. In relative terms has the most suitable specialisation and appears as efficient in all the FOS.

Although the quality effect tends to be small for most of the countries, it is relevant in some countries with high quality output such as Denmark and the Netherlands (in the latter country two thirds of its apparent inefficiency vanishes after taking quality into account). The composition inefficiency of most of the countries is fairly moderate in general. Nevertheless, it is more relevant for countries such as Luxembourg, the Baltic republics, Finland, Portugal, Denmark, Greece or the Netherlands. The absolute size of this type of inefficiency in these countries is greater than total pure inefficiency in relatively efficient countries such as Germany. As a percentage of total inefficiency it appears as fairly relevant in countries such as Germany (where it represents 66% of total inefficiency), Luxembourg (35.3%), Portugal (29.1%) or Greece (24.2%).

In summary, major differences can be seen in the efficiency levels of the EU countries' HEIs and their components. Figure 6 reported important differences in output per capita of the HEIs and posed the question of whether these differences were due to compositional inefficiencies, intra-field inefficiencies, differences in output quality or in the quantity of resources per capita. The results of the exercises performed allow us to advance in responding to this question.

Figure 10. Scientific research inefficiencies: quality effect, composition and intra-field inefficiency. 2012.
Percentages



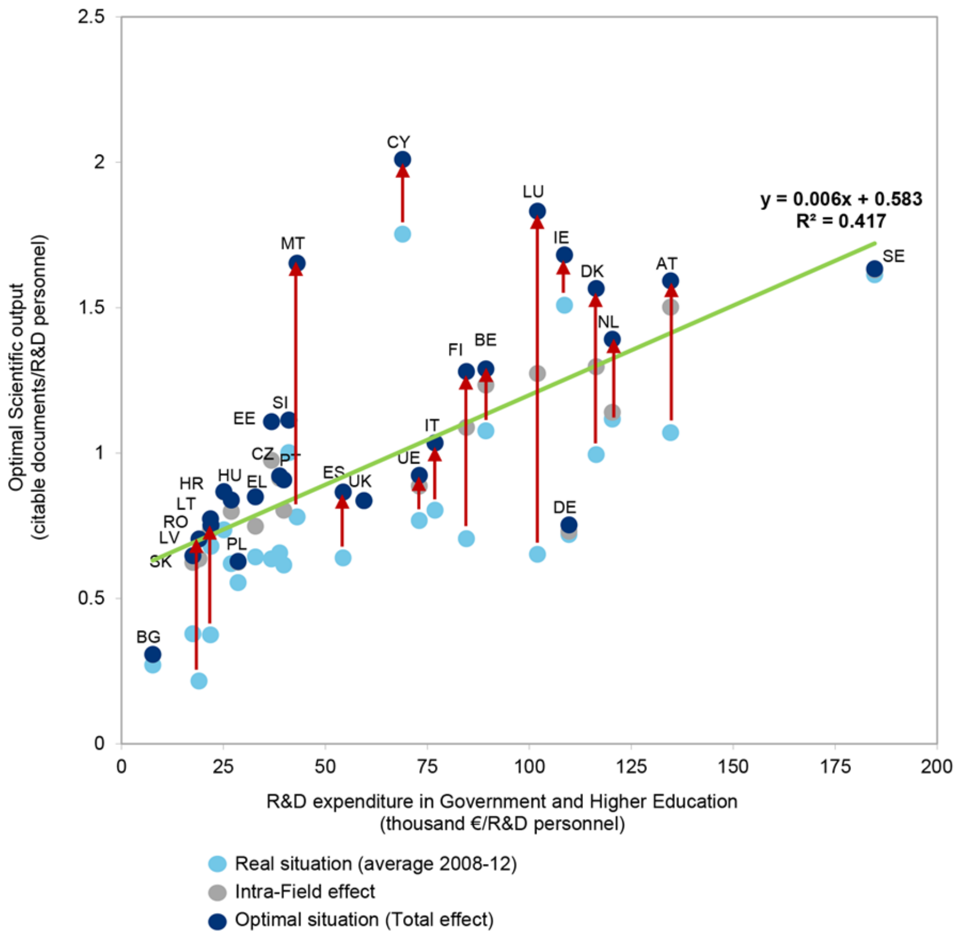
Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

Figure 11 shows that the countries whose HEIs devote more resources to R&D per capita also have higher scientific output per capita (real situation). There is a positive and significant relationship between the two variables in the EU countries. On the other hand, the figure shows that the widespread heterogeneity in output per capita is not only explained by the number of resources used, since some countries obtain a much higher output per capita with the same resources per capita than others. For example, Slovenia has a similar level of scientific output per capita to Denmark, while its R&D expenditure for every R&D personnel is one third that of Denmark; or the case of Croatia which has a similar output per capita to Germany with barely 25% of Germany's per capita expenditure. Indeed, the differences in R&D expenditure per capita explain little more than one third of the differences in output per capita. So are the huge differences in efficiency levels underlying the differences in output per capita?

If we consider that countries are efficient within each field of study in which they work (intra-field effect), all the countries will see an increase in their level of output per capita, taking the United Kingdom as the reference unit. Countries such as Latvia, Malta and Lithuania could double their scientific output if they were efficient in their fields of study. Other countries would significantly increase their scientific output, such as Finland (+54%), Austria (+40%), Czech Republic (+39%), Spain (+35%) or Italy (+29%).

Figure 11 also shows the effect that removing all inefficiencies would have, also considering the quality effect and the specialisation effect on output per capita (optimal situation). The blue dots represent maximum output per capita corrected for quality once inefficiencies have been removed. Logically, again all the countries improve, particularly the most inefficient ones. In this case countries like the Netherlands and Denmark would see an increase of 14% and 11% in their output due to the quality effect of their scientific output. However there is still considerable dispersion in the levels of output per capita in the HEIs.

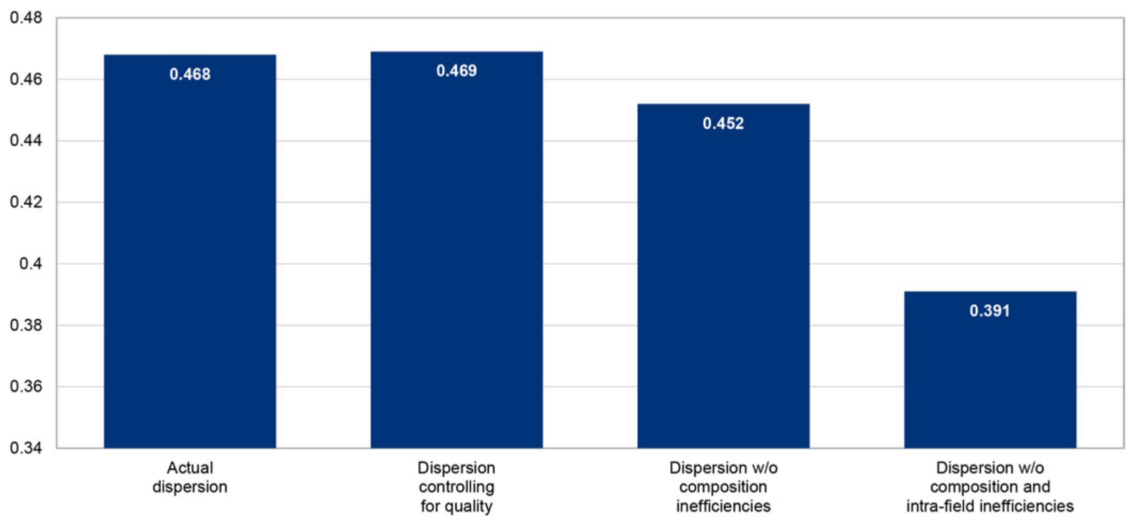
Figure 11. Maximum scientific output vs. R&D expenditure. EU countries. 2012



Source: SCImago Journal & Country Rank, Eurostat and own elaboration.

Figure 12 represents the deviation coefficient of the output per capita levels of the EU countries' HEIs, and of the outputs per capita once the different types of inefficiencies have been removed. If we removed the effect of quality, specialisation and the intra-field inefficiencies, the deviation coefficient would only decrease by 16.5%, from 0.468 to 0.391, mainly because of the intra-field inefficiencies. This is a non-negligible change. Nevertheless, most of heterogeneity in research output per capita would still remain. This indicates the key role that differences in the amount of resources per capita plays on output per capita within the EU.

Figure 12. Dispersion of the research output per capita
Deviation coefficient EU countries



7. CONCLUSIONS

It is widely accepted that a country's capacity to generate wealth and achieve high standards of well-being is closely linked to its capacity to generate knowledge. In the EU the generation and transmission of knowledge essentially falls to higher education institutions (HEIs). This study has analysed the research output of the EU's HEIs and has explored the determinants of the differences among them.

To this end a 5-step approach was designed to explicitly consider the quality of the universities' scientific output and their specialisation in terms of fields of science (FOS). This methodology allows us to decompose the differences in scientific output per researcher among countries in terms of differences in efficiency within each field (intra-field efficiency), differences in the FOS specialisations of the HEIs in each country (composition efficiency), quality effect and differences in R&D expenditure per researcher.

Results indicate that, on average, given the actual resources used, the scientific output of the HEIs could increase by around 20% in the EU if all the inefficiencies were removed.

Naturally, the total output of the factors and the outputs per capita in the research activity of the HEIs could increase by the same percentage.

The margins for improvements vary greatly across countries. Our results uncover large differences between countries in this subject Inefficiency is a particular problem in countries like Latvia, Luxembourg, Lithuania, Malta, Slovakia, but much lower in countries like the United Kingdom, Sweden or Germany, where research is carried out more efficiently.

When research output is controlled for by quality of scientific output, one of its key aspects, the results in general hold. However, the impact is considerable in some cases such as Denmark or the Netherlands. The Netherlands rises from 12th to 4th position in the efficiency ranking after taking into account the quality of output.

Most of the inefficiency estimated is intra-field (87.6% of total inefficiency), while the composition inefficiencies, linked to the specialisation in terms of the different fields of science, are generally lower (12.4% of the total). On the other hand, the magnitude of the latter type of inefficiency in some countries is higher than the the total inefficiency of others.

Relative inefficiency has a direct impact on the differences in research productivity among countries. One sixth of the heterogeneity in research output per capita would be due to the specialisation and the intra-field inefficiencies. Removing all inefficiencies, both intra-field inefficiencies and those due to the particular field of science specialisation, would lower the deviation coefficient of output per capita from around 0.47 to around 0.39.

All in all, the results confirm the importance of intangible aspects as determinants of the research productivity of the European HEIs. There are substantial differences in countries' levels of efficiency in using inputs in research activity. The results suggest that there is a wide margin for the EU to substantially increase research output, by up to almost 20%, without having to assign additional resources. This would require improvements in efficiency, especially in countries that are further away from best practices. This challenge must be taken up if higher levels of well-being are to be achieved in Europe. In addition, the amount of resources is also important. The results confirm that in the case of the EU countries research output per capita tends to grow, the higher the volume of resources per researcher. A large part of the differences in research output per capita across EU countries is associated with differences in this area and would persist even if all the countries were capable of completely removing their inefficiency.

In summary, increasing research output of the European HEIs is fundamental to attain smart development in Europe that can provide its citizens with higher levels of well-being. The possibilities for improvement are conditioned by the economic resources devoted to this activity, but there are considerable margins for improvement in the efficiency with which these resources are used that EU countries should take advantage of, especially in today's complicated economic and budgetary contexts.

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