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Trends of the European Scientific Publications in Comparison with other World Leaders over the Period 2015-2019

Scientific Disciplinary Sector(s)

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Content

I. INTRODUCTION

1. Bibliometrics and measurement of research outputs

In modern societies, shaped by communications 2.0 and social media, it has become easier than in the past to trace any action of individuals and institutions. Scientific publications are not exempt from this rule, *a fortiori* in democratic countries steered by the principles of transparency and accountability. In our area these principles have led to the definition and implementation of the concept of open science and open innovation in accordance to which results of research have to be made accessible to as many as possible potential beneficiaries. This happens or should happen without prejudice to the intellectual property rights.

Nowadays, the scientific research is a field whereby it is possible to define reliable indicators allowing to measure scientific production. This production is, traditionally, measured by:

I. The number of scientific works (articles, studies) a single researcher or institution has published over a given period of time in journals of excellence (e.g. Science, Nature, etc.) or others that after a careful analysis have been accepted in database of recognised prestige, such as Scopus in Europe, or Web of Science and Pub Med in the United States. The assessment of the journals by those who manage these databases concerns, above all, the way in which articles published have been evaluated, the so-called peer-peer review, in other words, the assessment made by other researchers;

II. The number of citations that a single researcher or institution receives from other researchers, or how many times over a given period, a publication of that researcher/ institution has been cited in the aforementioned databases. In this regard, complex indicators have been set out. They relate to both the impact in terms of citations of the entire production, or the impact of individual publications. The so-called H-index is determined by the number of publications of single author/institution that has, at least, that same number of citations. For example, a researcher who has produced 30 scientific papers each of which has reached at least 30 citations has an H-index of 30. This constitutes the minimum H-index (30) level in order for a scholar to get a certain international visibility.

To these two "traditional" indicators (in fact, biometrics has only a few decades of life), other two have recently been added. These are:

1) The impact of scientific production on technological innovation, or how much scientific work underpins patents of a single innovator, a group of innovators or institution. The fact that all patents are archived in national and international databases and the documentation for them is accessible, makes possible to measure this impact;

2) The social impact or the extent to which scientific production influences specialised media (scientific divulgation) and the general media (written press, social media, televisions, etc.)

Until recent years the monopolisation by the US group Thomson Scientific in the domain of biometrics measurements has remained quite stable. The Thomson's Journal Citation Reports (JCR) service, although frequently criticised, has been the standard for journals' comparison and the so-called "Impact Factor" or impact factor used in the JCR to classify the competitiveness of journals (the number of citations that on average an article published in that journal receives over certain period of time) has acquired an almost mystical importance within the scientific community, as a measure of the quality of a single publication in certain journals.

The inadequate use of this Impact Factor, which was originally created to measure the competitiveness of scientific journals, for assessing the competitiveness of single researchers, has been recently criticised by the Nobel Laureate Harold Varmus[1]. Similar critics have boosted the development of a European system of measurement of scientific productivity. This development has been driven by the need to define new indicators that are more appropriate to measure the scientific production of single researchers, groups of researchers or institutions. The H-index is an expression of this new vision.

The European SCIMago portal is managed with the direct participation of Public Universities and the Spanish National Research Council. Unlike the JCR (which is accessible only for subscribers), SCImago is freely available online. SCImago's additional advantage is that the Scopus database is wider than the Web of Science, used by JCR. Moreover, it is more attentive to non-English magazines and online journals.

It has to be noted that in the specific evaluation of academic institutions, there are also other classifications based on the analysis of different activities inherent to the academia, in particular, the didactics. However, the measurement of the quality and impact of teaching remains largely controversial, as is the choice of indicators and the relative weight to be assigned to each indicator. Consequently, most of the existing classifications are, for one to another reason, questioned and do not have the necessary robustness. In contrast, the measure of scientific production makes use of highly reliable indicators, on the relevance of which there is an ample consensus. This is the case, in particular, of SCImago rankings, which is considered as a world reference.

2. The role of the EU funds for research and innovation post-Brexit

The European Framework Programmes (FP) for research and innovation has triggered important advances in all scientific fields. Among those fields the biomedical research, whereby the United

[1] https://www.youtube.com/watch?v=ti1FU8gAs_M

Kingdom excels, has been the most prominent in Horizon 2020 fields (SCImago 2018). At present, this country is the third world power in scientific production, and the second in biomedical research scientific production. For this reason the withdrawal of UK from the Union may have serious, even catastrophic consequences (Hebebrand et al. 2019) for both the EU's and the British scientific and technological production, and their impact on the intentional arena. Such consequences could be mitigated, if the UK - after its withdrawal - managed to negotiate swiftly an agreement for association to the next FP - Horizon Europe (2021-2027). The negotiations of such agreement will largely depend on the way in which UK exits the Union.

Since 1984, the European FPs for Research and Technological Development[2] has played an important role in boosting science, research and innovation in the EU. With an progressively increasing budget - the first FP amounted for 3.8 billion EUR, while the future will amount for more than 100 billion EUR, these programmes contributed to the realisation of many collaborative projects, carried out jointly by researchers from different European universities, research centres, industrial consortia and SMEs. By doing so, they have largely contributed to reduce the gap between high-performing and less-performing EU countries, and to overcome the fragmentation of the European research and innovation landscape, which is one of the conditions to achieving a genuine European Research Area[3]. Thus, the FPs have allowed small groups, like ours, to participate in relevant European projects, such as School Children Mental Health in Europe (Husky et al. 2018) and the Joint Action on Mental Health and well-being (Rampazzo et al 2017), collaborating with leading research groups from UK and other European partners.

In spite of the considerable improvements, over the last years, in the definition and implementation of the successive European FPs for research and innovation, there are still certain critical points that merit being highlighted. Such criticism should not be seen in the context of the on-going tensions between "sovereignists" and “pro-Europeans", which has also been projected to the field of research and innovation policies (Ventriglio et al, 2019). Despite of the progressive simplification in the Rules of participation of the FPs, European researchers continue to have difficulties in drafting the research proposals and are still facing numerous bureaucratic bearers. This reality has resulted in the proliferation of private companies specialised in preparing projects on behalf of the researchers (Carta in press). Such practice differs considerably from what can be

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[2] From the current Framework Programme 8 - Horizon 2020 - the expression “technological development” has been replaced by “innovation”. This change has to be seen in the context of the Innovation Union, which is one of the flagship initiatives underpinning the Europe 2020 strategy.

[3] Article 179.1 of the Treaty on the Functioning of the European Union: “The Union shall have the objective of strengthening its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry, while promoting all the research activities deemed necessary by virtue of other Chapters of the Treaties”.

observed in other countries and regions of the world, in particular, in the United Sates. Thus, the need of "translating" researchers' ideas into a specific language of the respective European call for proposals illustrates a "gap of understanding" between the research community and those in charge of defining and implanting the European research and innovation policies via funding programmes and projects. (Carta in press).

This "gap of understanding" also appears clear when comparing the success rate of the 28 EU countries in Horizon 2020 calls (European Commission 2015), with the success rate in scientific production in the same countries (SCImago 2018) over the period 1996-2018. Researchers from the United Kingdom, the third country in the world for scientific production, after the United States and China, has a success rate lower than that of 9 EU countries, some of which stand under the 70th position in the ranking of scientific productivity. The case of Italy is even more emblematic, as being 8th in the world 4th in the EU in scientific production (Charter 2015), it is only 24th in the success rate of Horizon 2020 projects.

It would be worth reminding that ultimate goal of the European FPs is to support the best European research, on the basis of excellence and high-quality of the project proposals. This makes even more surpassing the absence of positive correlation between the scientific production of researchers and research teams per country and their rate of success in the European FPs. Thus, Malta - 11th in the success rate of Horizon 2020 projects - has 923 scientific articles published in 2018, Luxembourg - 8th in the success rate of Horizon 2020 projects - has 2271 scientific articles published in the same year, and Latvia - 5th in the success rate of Horizon 2020 projects - has 2267 scientific articles published in the same year, while the United Kingdom - 10th in the success rate of Horizon 2020 projects - has 211710 scientific articles published in 2018, and Italy - 24th in the success rate of Horizon 2020 projects - has 119,405 scientific articles published in the same year.

Another important critical aspect is the cost-effectiveness of the research funded by the European FP in comparison with the NIH of the United States. Recently, we have evaluated (Kirilov et al. 2018) the impact on scientific literature of a sample of projects funded by the FP7 on Active Ageing (AA) and elderly Quality of Life (QoL) in comparison to the same number of projects funded by the USA's National Institute of Health (NHI). The results show that the European and American projects have a similar impact in terms of a number of published articles and number of citations by published papers per single project. However, the FP7 European projects have lower cost-effectiveness compared to the American NIH projects.

The quantity and quality of what has been published relate directly to the competitiveness capacity of the respective researcher or research team. This aspect appears to be underestimated by those who design and implement the European FPs. In addition, the record of publications of the researchers is not taken into account as a criterion for evaluation of the project proposals, which constitutes an important difference in comparison with the NHI evaluation's approach (Carta et al. 2019).

Although the European Union, as a whole, maintains an excellent scientific production, the EU Member States, with the exception of the UK, have been losing positions in the world ranking. Among the strongest European countries in terms of scientific production, only Germany, Italy, Poland and Sweden maintained the SCImago ranking for scientific productivity in 2018 identical to that they had ten years ago, respectively 4th, 8th, 17th and 20th, while France, Spain, the Netherlands, Belgium, Portugal, Finland, Romania, Ireland, Hungary and Austria have lost positions [SCIMAGO 2018].

The criticism towards the European research and innovation goes beyond the European FPs and relates mainly to the financial resources single Member Sates allocate to research and innovation activities. In 2002 Member States agreed on the Barcelona target[4] to increase investment in scientific R&D to 3 % of national GDP, with one third of funding provided by governments and two thirds by business. The aim was to catch up with high R&D expenditure countries such as South Korea, the US and Japan. In 2010 this target become one of the five targets of the "Europe 2020 A strategy for smart, sustainable and inclusive growth"[5].

However, the results achieved until now are disappointing. Thus, according to 2018 figures from Eurostat[6], the highest R&D intensities among the Member States were recorded in Sweden (3.25 %) and Austria (3.09 %). These were the only two Member States to report levels of R&D intensity above the 'Barcelona target' of 3.00 %, followed by Germany (2.94 %), Denmark (2.87 %) and Finland 2.75 %. Overall, in accordance with Eurostat, the EU lags behind its main competitors. In 2017 the R&D intensity was lower than in South Korea (4.55%), Japan (3.20%) and the United States (2.78%), while it was at about the same level as in China (2.13%).

The lack of sufficient funding is particularly relevant in certain areas, such as the biomedical research considering, in particular, the fact that the national health systems in the EU have to guarantee basic health assistance to all citizens. This makes them the largest customers of the pharmaceutical companies. Consequently, high-quality independent research is of utmost importance to underpin sustainable health care system in the EU, as an essential part of the European social market economy[7].

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[4] https://ec.europa.eu/invest-in-research/action/history_en.htm
[5] https://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
[6] https://ec.europa.eu/eurostat/statistics-explained/index.php/R_%26_D_expenditure
[7] Article 3(3) of the Treaty on European Union (TEU)

II. OBJECTIVES

1) Evaluate the trends in the scientific production in the European Union over the last four years (2015-2019)

2) Compare the European scientific production with that of its main world competitors, China and United States

3) Identify the European strengths and weaknesses with a particular attention to competitiveness-linked indictors

III. METHODOLOGY

For each of the following groups: European Union post-Brexit; Europe; United Kingdom; United States; China; Asia without China; Private companies; and Italy; the 10 best scientific production's institutes will be selected, according to the SCImago database for 2019.

In each group the average ranking will be calculated as the average of the rank of each of the 10 best institutions from 2015 to 2019 inclusive. The average trend of the total scientific productivity (SCImago global score) will be calculated, as well as the trend of the two major sub-components of the indicator ("Research" and "Innovation").

Some universities or institutions entered the ranking only in 2019. For them the calculation of the 2015-2019 difference in the respective group did not take into account these specific institutions. In this case, therefore, we have calculated two differentiated averages in 2019, one with all values, the other one without non-repeated values. In certain cases, an "intention-to-treat" approach has been followed.

The effect of the time trend in the comparison between the groups has been analysed through multivariate analysis of variance (MANOVA).

Each group has been compared following the three indicators (Total Scimago Score, Research and Innovation) with the sum of the other groups referred to the 2015 and the 2019 time trends. SCImago ranking has been considered as the dependent variable, while the group and time have been considered as independent variables.

SHImago Ranking

The SCImago Institutions Rankings (SIR), is a measure of the quality of the production of scientific institutions in the world. It is a classification obtained on the basis of the sum of three different sets of indicators: the bibliometric performance of the research ("Research" encompasses the points 1 and 2 previously illustrated) is the most important dimension and represents 50% on the final result; the impact on innovation ("Innovation" point 3, represents 30% on the final result). The calculation is based on the SCOPUS scientific publications.

For each macro-sector, in which scientific production is classified, it is possible to obtain distribution graphs of the various indicators. The attribution is carried out with a computerised method, and also verified manually.

The criterion for inclusion is that an institution / university has published at least 100 articles indexed in the SCOPUS database during the last year of the selected period of time. The indicators for innovation are calculated on the PATSTAT database.

The web visibility indicators are calculated on Google and Ahrefs (Altmetrics from PlumX metrics and Mendeley).

Indicators

The sub-components of the Research indicator (representing 50%) are:

1) Normalised Impact (NI) - 13%: the values show the relationship between the average scientific impact (number of citations) of a single institution's publications compared to the world average normalised on a score of 1, for example a NI score of 0.8 means that the institution is mentioned 20% below the world average;
2) Excellence with Leadership (EwL) - 8%: produced by the number of scientific articles in which the main author belongs to the institution considered;
3) Output (O) - 8%: the total number of documents published in scientific journals indexed on Scopus;
4) Publications in journals that are not published by the institution considered (NotOJ) - 3%: the number of articles;
5) Own Journals (OJ) - 3%: number of journals published by the institution;
6) International Collaborations (IC) - 2%: scientific articles produced by the institute in collaboration with other institutions;
7) High quality publications (Q1) - 2%: number of publications that an institution publishes in journals belonging to the first quartile of the SCImago Journal Rank;

8) Excellence (Exc) - 2%: indicates the number of scientific articles published by the institution considered included in the 10% of the most cited articles in the respective fields;
9) Scientific Leadership (L) - 5%: it is the number of scientific articles whose main author belongs to the institution considered;
10) Open Access (OA) - 2%: percentage of indexed documents published in Open Access journals.
11) Scientific Talent Pool (STP): the total number of authors and the articles of the institution considered over a given period of time.

The sub-components of the Innovation indicator (representing 30%) are:

1) Innovative knowledge (IK) - 10%: scientific publications produced by an institution cited in patents in the PATSTAT database;
2) Technological impact (TI) - 5%: percentage of the total scientific publications of an institution cited in the patents;
3) Patents (PT) - 5%: number of patent applications traceable in PATSTAT for each institution.

IV. RESULTS

The first group - the European Union post-Brexit - encompasses ten universities located in Belgium, the Netherlands, Denmark, Sweden, France and Germany, respectively. The results presented on the tables 1-3 indicate that these universities tend to lose positions in the overall world rank. As regards Research indicator, they have been moving slightly upwards in the rank which, however, contrasts with a considerable descent in the “Innovation" rank.

Similar is the picture with the second group - Europe - which includes five universities in UK, two in the Netherlands, and one in Switzerland, Denmark and Belgium respectively (tables 4-6); and with the third group - the United Kingdom’s ten top universities (tables 7-9).

In the fourth group - the United States’ ten top universities (tables 10-12), we observe a tendency to go a little down in the overall world rank and in the “Research” world rank. However, as regards the Innovation indicator, the fall appears less pronounced than in the EU (Rank Difference Vs EU post-Brexit (-174.2 ± 11.7) $F=33.487$ df 1, 16, 17 $p<0.0001$).

The fifth group - China’s ten top universities (tables 13-15), there is a rise in the overall rank and in the rank of Research and Innovation, respectively. On the contrary, in the sixth group - ten top universities in Asia without China (tables 16-18), we observe a decrease in the all three ranks.

The seventh group composed by Private companies specialised, mainly, in digital technologies, Internet services and products, and Pharmaceuticals (tables 19-21), we see considerable ascent in the general and innovation ranks and a slow decrease in the research rank.

The Italian top ten universities compose the eight group (tables 22-24), in which we observe a descent in all three ranks, the “Innovation” one being particularly pronounced. At this point, it has appeared interesting to see the ranking of the University of Cagliari, to which our research team belongs, in the world rank of scientific production (figure 1) and innovation (figure 2), respectively, over the last ten years. Following the fluctuations in the ranking, we can see that the University keeps its position in scientific production - 582 in 2009, 583 in 2019. There has been a notable improvement in the ranking - 438 position in 2015 -, which coincides with equal improvement in the innovation rank over the same period - 302 position 2014 and 307 position in 2015. This illustrates the positive correlation between the number of scientific publication and the innovation.

In the tables 25, 26 and 27, respectively, we can observe the comparison between the European Union post-Brexit ten top universities and the other seven groups in 2019[8]. In the overall rank, the average ranking of these universities is inferior to groups Europe, UK, USA, China and Private companies, and the difference is statistically significant in the case of Europe, USA, China and Private companies’ groups. The average ranking of the European Union post-Brexit ten top universities is superior to the groups Asia without China and Italy, in the case of the later the difference is statistically significant.

In the table 28, we observe the comparison in the overall rank of the ten top universities/companies between their average rankings in 2015 and in 2019. The following groups - European Union post-Brexit, Europe, UK, USA, Asia without China and Italy - have lost positions, being the difference statistically significant in the case of the Italian top ten universities. The other two groups - China and Private companies - have gained positions in the overall rank, being in both cases the difference statistically significant.

The table 29 represents the comparison in the “Research” rank of the ten top universities/companies between their average rankings in 2015 and in 2019. The following groups - European Union post-Brexit, Europe, UK, China and Private companies - have moved upwards in the rank without a statistically significant difference. The other three groups - USA, Asia without China and Italy - have gone down in the rank, being the difference statistically significant in the case of group of top ten universities from Asia without China.

The table 30 shows the comparison in the “Innovation” rank of the ten top universities/companies between their average rankings in 2015 and in 2019. The following groups -

[8] Data have been collected in September 2019

European Union post-Brexit, Europe, UK, USA, Asia without China and Italy - have moved downwards in the rank, being the difference statistically significant in the case of the top ten universities from the European Union post-Brexit, the United Kingdom and Italy, respectively. The other two groups - China and Private companies - have risen in the ranking with a statistically significant difference in both cases.

Table 1. Means Overall Rank of the 10 Top Universities in the European Union post-Brexit

University (world ranking)	2015	2016	2017	2018	2019
1. Catholic University of Leuven(72)	43	38	55	74	72
2. University of Copenhagen (73)	85	58	66	96	75
3. Utrecht University (81)	55	55	63	94	81
4. University of Amsterdam (88)	80	79	79	102	88
5. Karolinska Institute (105)	71	77	93	141	105
6. Sorbonne Université (112)	NR	NR	NR	NR	112
7. Ghent University (114)	91	86	96	129	114
8. Technische Universitat Munchen (116)	61	47	102	124	116
9. University of Groningen (133)	120	127	118	171	133
10. Leiden University (134)	103	90	99	166	134
Mean	78.8	73.0	85.7	121.9	103.0
Standard Deviation	22.8	25.5	19.8	31.5	21.6
Repeated Mean	78.8	73.0	85.7	121.9	102.0
Repeated Standard Deviation	22.8	25.5	19.8	31.5	22.6

Rank Difference 2015-2019 = -23.2±18.2
Source SCImago modified

Table 2. Mean in the Rank "Research" 10 Top Universities in the European Union post-Brexit

University (world ranking)	2015	2016	2017	2018	2019
1. Catholic University of Leuven(72)	58	53	50	51	52
2. University of Copenhagen (75)	80	77	64	62	49
3. Utrecht University (81)	60	64	56	61	56
4. University of Amsterdam (88)	69	74	62	66	57
5. Karolinska Institute (105)	104	102	93	100	83
6. Sorbonne Université (112)	NR	NR	NR	NR	38
7. Ghent University (1149)	81	81	69	76	78
8. Technische Universitat Munchen (116)	84	78	98	96	97
9. University of Groningen (133)	102	110	92	102	89
10. Leiden University (134)	113	132	113	123	109
Mean	83.4	85.6	77.4	81.9	70.8
Standard Deviation	18.4	23.2	20.7	22.8	22.3
Repeated Mean	83.4	85.6	77.4	81.9	74.4
Repeated Standard Deviation	18.4	23.2	20.7	22.8	20.5

Rank Difference 2015-2019 = +8.5±12.3
Source SCImago modified

Table 3. Means in the Rank "Innovation" 10 Top Universities in the European Union post-Brexit

University (world ranking)	2015	2016	2017	2018	2019
1. Catholic University of Leuven(72)	44	36	71	190	194
2. University of Copenhagen (73)	83	59	87	238	263
3. Utrecht University (81)	58	67	82	248	262
4. University of Amsterdam (88)	92	89	112	267	287
5. Karolinska Institute (105)	46	63	79	223	244
6. Sorbonne Université (112)	NR	NR	NR	NR	260

7. Ghent University (1149	93	87	147	272	296
8. Technische Universitat Munchen (116)	47	39	114	221	219
9. University of Groningen (133)	146	169	158	303	323
10. Leiden University (134)	81	62	90	232	261
Mean	76.7	74.5	104.4	243.7	260.9
Standard Deviation	30.9	37.4	29.1	31.4	35.1
Repeated Mean	76.7	74.5	104.4	243.7	261.0
Repeated Standard Deviation	30.9	37.4	29.1	31.4	36.9

Rank Difference 2015-2019 = -174.2±11.7
Source SCImago modified

Table 4. Means in the Overall Rank 10 Top Universities in Europe

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	16	14	13	15	14
2 University College London (18)	23	26	23	30	18
3 University of Cambridge *(32)	25	19	27	31	32
4. Imperial College London (45)	23	22	37	52	45
5. Swiss Federal Institute of Technology (55)	51	49	50	50	55
6. Catholic University of Leuven(72)	43	38	55	74	72
7. University of Copenhagen (75)	85	58	66	96	75
8. Utrecht University (81)	55	55	63	94	81
9. University of Amsterdam (88)	80	79	79	102	88
10. Kings College London (92)	91	74	85	114	92
Mean	49.2	43.4	49.8	65.8	57.2
Standard Deviation	26.6	22.0	23.04	33.0	27.9
Repeated Mean					

Repeated Standard Deviation					

Rank Difference 2015-2019 = -7.0±11.9
Source SCImago modified

Table 5. Means Rank in Research 10 Top Universities in Europe

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	14	12	12	13	13
2 University College London (18)	21	19	17	16	14
3 University of Cambridge *(32)	20	20	22	22	23
4. Imperial College London (45)	29	29	28	32	27
5. Swiss Federal Institute of Technology (55)	44	44	44	43	44
6. Catholic University of Leuven(72)	58	53	50	51	52
7. University of Copenhagen (75)	80	77	64	62	49
8. Utrecht University (81)	60	64	56	61	56
9. University of Amsterdam (88)	69	74	62	66	57
10. Kings College London (92)	75	70	65	71	59
Mean	47.0	46.2	42.0	43.7	39.4
Standard Deviation	23.4	23.5	19.5	20.6	17.3
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = 7.6±9.5
Source SCImago modified

Table 6. Means in the Innovation 10 Top Universities in Europe

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	22	17	23	138	151

2 University College London (18)	42	31	43	203	180
3 University of Cambridge *(32)	38	27	42	189	191
4. Imperial College London (45)	21	15	49	196	196
5. Swiss Federal Institute of Technology (55)	70	82	75	170	172
6. Catholic University of Leuven(72)	44	36	71	190	194
7. University of Copenhagen (75)	83	59	87	238	263
8. Utrecht University (81)	58	67	82	248	262
9. University of Amsterdam (88)	92	89	112	267	287
10. Kings College London (92)	102	87	117	281	289
Mean	52.2	51.0	70.1	212.0	218.5
Standard Deviation	23.9	27.7	29.3	42.8	48.6
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = -161.3±30.7
Source SCImago modified

Table 7. Means in the Overall Rank 10 Top Universities in the UK

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	16	14	13	15	14
2 University College London (18)	23	26	23	30	18
3 University of Cambridge *(32)	25	19	27	31	32
4. Imperial College London (45)	23	22	37	52	45
5. Kings College London (92)	91	74	85	114	92
6. The University of Manchester (93)	83	89	84	106	93
7. The University of Edinburgh (96)	93	95	103	111	96

8. University of Glasgow (181)	168	172	180	230	181
9. University of Bristol (187)	145	141	170	235	187
10. University of Nottingham (195)	158	180	183	219	195
Mean	82.5	83.2	90.5	114.3	95.3
Standard Deviation	56.4	60.6	63.6	81.7	66.9
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = -11.8±15.0
Source SCImago modified

Table 8. Means Rank in Research 10 Top Universities in the UK

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	14	12	12	13	13
2 University College London (18)	21	19	17	16	14
3 University of Cambridge *(32)	20	20	22	22	23
4. Imperial College London (45)	29	29	28	32	27
5. Kings College London (92)	91	74	85	114	92
6. The University of Manchester (93)	61	59	58	63	52
7. The University of Edinburgh (96)	78	76	73	77	69
8. University of Glasgow (181)	159	157	158	157	138
9. University of Bristol (187)	112	112	117	120	99
10. University of Nottingham (195)	125	133	131	119	108
Mean	71.0	69.1	70.1	73.3	63.5
Standard Deviation	47.9	48.5	49.2	49.3	42.1
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = **+7.5±7.5**
Source SCImago modified

Table 9. Means in the Innovation 10 Top Universities in the UK

University (world ranking)	2015	2016	2017	2018	2019
1 Oxford (14)	22	17	23	138	151
2 University College London (18)	42	31	43	203	180
3 University of Cambridge *(32)	38	27	42	189	191
4. Imperial College London (45)	21	15	49	196	196
5. Kings College London (92)	102	87	117	281	289
6. The University of Manchester (93)	118	148	141	300	303
7. The University of Edinburgh (96)	98	113	156	287	295
8. University of Glasgow (181)	181	170	204	310	330
9. University of Bristol (187)	188	203	244	355	369
10. University of Nottingham (195)	209	264	236	345	363
Mean	101.9	107.5	125.5	260.4	266.7
Standard Deviation	67.8	82.8	79.8	69.8	76.1
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = -164.8±**21.9**
Source SCImago modified

Table 10. Mean in the Overall Score Rank 10 Top Universities in the United States

University (world ranking)	2015	2016	2017	2018	2019
1. Harvard University (4)	3	3	3	3	4
2. Harvard Medical School (5)					5
3. Massachusetts Institute of Technology (8)	9	10	8	9	8

4. Stanford University (9)	8	7	6	7	9
5. Johns Hopkins University (12)	14	13	9	13	12
6. University of Michigan, Ann Arbor (17)	11	11	12	14	17
7. University of Washington (19)	19	20	18	17	19
8. University of Pennsylvania (23)	17	17	14	19	20
9. University of California, Los Angeles (27)	12	16	17	22	27
10. Columbia University (33)	31	30	33	36	33
Mean	13.8	14.1	13.3	15.5	15.4
Standard Deviation	7.6	7.6	8.3	9.1	9.1
Repeated Mean	13.8	14.1	13.3	15.5	15.4
Repeated Standard Deviation	7.6	7.6	8.3	9.1	9.1

Rank Difference 2015-2019 = **-2.7±4.8**
Rank difference vs EU (8.5±12.3) F=9.224 df 1, 16, 17 p = 0.008

Source SCImago modified

Table 11. Mean in the Rank "Research" 10 Top Universities in the United States

University (world ranking)	**2015**	**2016**	**2017**	**2018**	**2019**
1. Harvard University (4)	2	2	2	13	6
2. Harvard Medical School (5)					8
3. Massachusetts Institute of Technology (8)	19	22	23	24	22
4. Stanford University (9)	7	8	8	7	10
5. Johns Hopkins University (12)	13	15	14	14	16
6. University of Michigan, Ann Arbor (17)	10	9	9	10	15
7. University of Washington (19)	16	17	16	19	21
8. University of Pennsylvania (23)	22	23	23	26	25

9. University of California, Los Angeles (27)	15	16	18	23	24
10. Columbia University (33)	24	25	24	27	26
Mean	14.2	15.2	15.2	18.1	17.3
Standard Deviation	6.6	7.2	7.2	6.9	7.0
Repeated Mean	14.2	15.2	15.2	18.1	18.3
Repeated Standard Deviation	6.6	7.2	7.2	6.9	6.6

Rank Difference 2015-2019 = **-4.1±1.9**
Rank difference vs EU (8.5±12.3) F=9.224 df 1, 16, 17 p = 0.008

Source SCImago modified

Table 12. Means in the Rank Innovation 10 Top Universities in the United States

University (world ranking)	**2015**	**2016**	**2017**	**2018**	**2019**
1. Harvard University (4)	3	3	3	3	4
2. Harvard Medical School (5)					13
3. Massachusetts Institute of Technology (8)	6	8	6	25	11
4. Stanford University (9)	8	5	8	48	44
5. Johns Hopkins University (12)	14	11	10	81	99
6. University of Michigan, Ann Arbor (17)	11	14	25	156	157
7. University of Washington (19)	24	33	19	126	132
8. University of Pennsylvania (23)	23	26	14	112	108
9. University of California, Los Angeles (27)	10	20	12	113	124
10. Columbia University (33)	55	48	44	184	172
Mean	17.1	18.7	15.7	94.2	86.4
Standard Deviation	15.0	13.9	11.8	56.7	60.1
Repeated Mean	17.1	18.7	15.7	94.2	94.5

Repeated Standard Deviation	15.0	13.9	11.8	56.7	57.8

Rank Difference 2015-2019 = -77.4±48.8
Rank Difference Vs EU post-Brexit (-174.2±11.7) F=33.487 df 1, 16, 17 p<0.0001
Source SCImago modified

Table 13. Means Overall Rank 10 Top Universities in China

University (world ranking)	**2015**	**2016**	**2017**	**2018**	**2019**
1. Tsinghua University (13)	32	34	15	11	13
2. The University of Hong Kong (25)	155	133	117	24	25
3. Peking University (28)	40	42	22	20	28
4. Zhejiang University (29)	47	43	23	18	29
5. Shanghai Jiao Tong University (30)	67	60	35	28	30
6. Graduate University of the Chinese Academy of Sciences (59)	110	116	42	84	59
7. Fudan University (91)	115	106	52	76	91
8. Huazhong University of Science and Technology (101)	140	133	78	91	101
9. Harbin Institute of Technology (117)	144	149	101	90	117
10. Sichuan University (125)	194	164	105	126	125
Mean	104.4	98.0	59.0	56.8	61.8
Standard Devistion	52.5	46.3	36.2	38.7	40.5
Repeated Mean					
Repeated Standard Devistion					

Rank Difference 2015-2019 = **+38.0±22.4**
Rank difference vs Europe (-23.2±18.2) F=**29.459** df 1, 17, 18 p<0.0001
Source SCImago modified

Table 14. Mean in the Rank “Research” 10 Top Universities in China

University (world ranking)	2015	2016	2017	2018	2019
1. Tsinghua University (13)	18	14	7	8	9
2. The University of Hong Kong (25)	122	124	82	12	18
3. Peking University (28)	27	22	19	15	20
4. Zhejiang University (29)	26	21	20	10	25
5. Shanghai Jiao Tong University (30)	41	35	32	21	23
6. Graduate University of the Chinese Academy of Sciences (59)	82	63	67	64	43
7. Fudan University (91)	87	72	65	70	75
8. Huazhong University of Science and Technology (101)	83	66	59	55	65
9. Harbin Institute of Technology (117)	73	63	63	69	79
10. Sichuan University (125)	122	98	79	79	86
Mean	68.1	57.8	49.3	40.3	44.3
Standard Deviation	36.4	33.7	27.8	27.8	27.7
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = **+15.5±12.1**
Rank difference vs EU (8.5±12.3) F=1.561 df 1, 17, 18 p = 0.228

Table 15. Means in the Rank Innovation 10 Top Universities in China

University (world ranking)	2015	2016	2017	2018	2019
1. Tsinghua University (13)	84	144	29	67	63
2 The University of Hong Kong (25)	183	174	182	141	145
3. Peking University (28)	89	142	28	98	116
4. Zhejiang University (29)	125	159	32	56	67
5. Shanghai Jiao Tong University (30)	134	163	45	97	110
6. Graduate University of the Chinese Academy of Sciences (59)	155	222	26	155	189

7. Fudan University (91)	162	168	49	143	185
8. Huazhong University of Science and Technology (101)	244	313	127	214	221
9. Harbin Institute of Technology (117)	296	355	193	179	243
10. Sichuan University (125)	260	276	142	138	259
Mean	183.4	224.7	78.4	134.5	166.5
Standard Deviation	76.4	76.5	57.1	51.3	68.3
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = **+16.9±35.5**
Rank difference vs Europe (-174.2±11.7) F=236.445 df 1, 17, 18 p<0.0001
Source SCImago modified

Table 16. Means Overall Rank 10 Top Universities in Asia without China

University (world ranking)	2015	2016	2017	2018	2019
1. University of Tokyo (42)	22	18	31	42	42
2. National University of Singapore (46)	35	37	32	38	46
3. Seoul National University (69)	65	60	40	64	69
4. Nanyang Technological University (82)	94	94	48	59	82
5. Kyoto University (99)	46	45	69	104	99
6. Osaka University (140)	71	65	96	158	140
7. National Taiwan University (157)	102	114	97	147	157
8. Yonsei University (169)	155	148	122	182	169
9. Korea Advanced Institute of Science and Technology (190)	147	135	113	156	190
10. Tohoku University (194)	108	124	111	188	194
Mean	84.5	84.0	75.9	113.8	118.8

Standard Deviation	46.7	42.8	34.1	56.1	52.3
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = -33.3±28.28
Rank difference vs Europe
Source SCImago modified

Table 17. Means Rank "Research" 10 Top Universities in Asia without China

University (world ranking)	2015	2016	2017	2018	2019
1. University of Tokyo (42)	28	27	27	33	31
2. National University of Singapore (46)	33	31	30	31	36
3. Seoul National University (69)	63	57	55	60	61
4. Nanyang Technological University (82)	55	48	45	47	64
5. Kyoto University (99)	66	69	75	78	80
6. Osaka University (140)	94	99	112	114	123
7. National Taiwan University (157)	83	87	83	107	135
8. Yonsei University (169)	136	131	130	135	145
9. Korea Advanced Institute of Science and Technology (190)	144	153	151	158	217
10. Tohoku University (194)	108	124	111	188	194
Mean	81.0	82.6	81.9	95.1	108.6
Standard Deviation	37.7	41.3	40.8	51.4	61.3
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = -27.6±30.0
Rank difference vs Europe (-23.2±18.2)
Source SCImago modified

Table 18 Means Rank "Innovation" 10 Top Universities in Asia without China

University (world ranking)	2015	2016	2017	2018	2019
1. University of Tokyo (42)	16	9	35	156	161
2. National University of Singapore (46)	39	61	31	117	119
3. Seoul National University (69)	82	91	37	133	165
4. Nanyang Technological University (82)	157	200	57	151	149
5. Kyoto University (99)	37	42	59	214	240
6. Osaka University (140)	52	49	68	230	246
7. National Taiwan University (157)	118	168	104	243	250
8. Yonsei University (169)	167	188	114	229	255
9. Korea Advanced Institute of Science and Technology (190)	119	165	98	136	151
10. Tohoku University (194)	120	172	112	261	300
Mean	90.7	115.5	71.5	187	188.1
Standard Deviation	50.3	65.9	31.2	50.6	50.1
Repeated Mean					
Repeated Standard Deviation					

Rank Difference 2015-2019 = **-91.1±76.1**
Rank difference vs Europe (-23.2±18.2) F=**10.780** df 1, 16, 17 p = 0.005
Source SCImago modified

Table 19. Means Overall Rank 10 Private Companies

Private Company (world ranking)	2015	2016	2017	2018	2019
1. Google (10)	5	5	7	5	10
2. Facebook, Inc. (15)	118	118	118	122	165
3. Microsoft Corp (36)	177	177	177	8	36

4. Microsoft, USA (37)					37
5. Samsung Corp (43)	385	385	385	37	43
6. Regeneron Pharmaceuticals Inc (48)	41	41	41	41	48
7. Microsoft Research, Asia (63)	206	327	63	63	63
8. Hoffmann-La Roche, Ltd., United States (67)	95	84	95	40	67
9. F. Hoffmann-La Roche (70)	88	80	81	45	70
10. IBM United States (72)					7
Mean	139.3	152.1	120.87	45.1	54.6
Standard Deviation	11.2	127.6	110.6	34.1	42.1
Repeated Mean	139.3	152.1	120.87	45.1	62.7
Repeated Standard Deviation	11.2	127.6	110.6	34.1	47.7

Rank Difference 2015-2019 = 76.6±119.2
Rank difference vs EU
Source SCImago modified

Table 20. Means Rank "Research" 10 Private Companies

Private Company (world ranking)	**2015**	**2016**	**2017**	**2018**	**2019**
1. Google (10)	165	199	155	116	103
2. Facebook, Inc. (15)	228	228	228	4	15
3. Microsoft Corp (36)	143	143	143	129	151
4. Microsoft, USA (37)					165
5. Samsung Corp (43)	247	247	347	340	272
6. Regeneron Pharmaceuticals Inc (48)	316	316	316	316	269
7. Microsoft Research, Asia (63)	105	184			197
8. Hoffmann-La Roche, Ltd., United States (67)	261	283	294	301	291
9. F. Hoffmann-La Roche (70)	245	263	273	280	277

10. IBM United States (72)					298
Mean	213.7	232.8	250.8	212.2	203.8
Standard Deviation	63.4	52.6	72.8	118.9	89.9
Repeated Mean	213.7	232.8	250.8	212.2	196.8
Repeated Standard Deviation	63.4	52.6	72.8	118.9	93.6

Rank Difference 2015-2019 = -12.9±53.6
Rank difference vs EU (-23.2±18.2) F=**0.300** df 1, 17, 18 p = 0.591
Source SCImago modified

Table 21. Means Rank "Innovation" 10 Private Companies

Private Company (world ranking)	**2015**	**2016**	**2017**	**2018**	**2019**
1. Google (10)	273	287	303	92	47
2. Facebook, Inc. (15)	330	330	330	160	141
3. Microsoft Corp (36)	203	203	203	24	23
4. Microsoft, USA (37)					20
5. Samsung Corp (43)	237	237	237	7	5
6. Regeneron Pharmaceuticals Inc (48)	4	4	4	4	3
7. Microsoft Research, Asia (63)	311	381			65
8. Hoffmann-La Roche, Ltd., United States (67)	28	21	22	6	12
9. F. Hoffmann-La Roche (70)	25	22	15	9	15
10. IBM United States (72)					17
Mean	176.3	185.6	159.1	43.1	34.8
Standard Deviation	127.5	141.0	131.7	55.8	39.8
Repeated Mean	176.3	185.6	159.1	43.1	38.8
Repeated Standard Deviation	127.5	141.0	131.7	55.8	45.5

Rank Difference 2015-2019 = +**138.7±101.77**

Rank difference vs EU (-23.2±18.2) F = **0.300** df 1, 17, 18 p = 0.591
Source SCImago modified

Table 22. Means Overall Rank 10 Top Universities in Italy

	2015	**2016**	**2017**	**2018**	**2019**
1.Sapienza	136	121	119	183	138
2. Milano	128	140	140	230	177
3. Padova	156	145	160	230	191
4. Bologna	142	140	163	231	210
5. Na-Federico II	206	208	185	265	222
6. Torino	203	201	228	320	275
7. Firenze	255	251	259	351	315
8. Pisa	244	236	297	357	336
9.MIpolitecnico	284	278	280	334	375
10. Tor Vergata	291	295	324	417	401
Mean	204.5	201.5	215.5	291.8	264.0
Standard Deviation	58.9	51,69	68.12	70.64	85.11

Rank Difference 2015-2019 = **-10.1± 54.3**
Rank difference vs Europe (-23.2±18.2) F=8.05 df 1,17,18 p = 0.011
Source SCImago modified

Table 23 Mean in the Rank "Research" 10 Top Universities in Italy

	2015	**2016**	**2017**	**2018**	**2019**
1. Sapienza	94	80	76	81	82
2. Milano	141	139	134	122	118
3. Padova	193	207	230	348	350

4. Bologna	119	119	123	128	126
5. Na-Federico II	163	164	151	147	140
6. Torino	202	201	107	194	179
7. Firenze	194	193	188	192	174
8. Pisa	213	215	213	210	220
9. MIpolitecnico	183	180	180	180	210
10. Tor Vergata	248	255	254	254	250
Mean	175.0	175.3	165.6	185.6	184.9
Standard Deviation	43.87	78.60	54.23	81.82	73.52

Rank Difference 2015-2019 = **-9.9± 34.2**
Rank difference vs Europe (8.5±12.3) F=1.01 df 1, 17, 18 p = 0.330
Source SCImago modified

Table 24. Means in the Rank Innovation 10 Top Universities Italy

	2015	**2016**	**2017**	**2018**	**2019**
1. Sapienza	205	208	218	363	365
2. Milano	114	163	167	319	340
3. Padova	193	207	230	348	350
4. Bologna	174	201	224	343	356
5. Na-Federico II	215	266	232	341	333
6. Torino	156	193	228	338	364
7. Firenze	253	276	281	378	396
8. Pisa	213	228	290	368	384
9. MIpolitecnico	308	329	305	379	387
10. Tor Vergata	229	267	287	363	382
Mean	206.0	233.8	246.2	354.0	365.7
Standard Deviation	50.42	47.07	40.75	18.74	20.11

Rank Difference 2015-2019 = **-159.7± 39.9**
Rank difference vs Europe (-174.2±11.7) F=1.01 df 1, 17, 18 p = 0.330
Source SCImago modified

Figure 1. Trend of the University of Cagliari in the world rank of scientific productivity by institutions

438th

443rd 444th

463rd

483rd

515th

539th

549th

567th

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582
nd

200
9

200
9

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11

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20
13

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16

20
17

20
18

2019

Figure 2. Trend of the University of Cagliari in the world rank of Innovation by institutions

302nd

307th

335th

341st

347th 350th 352nd

368th

373
rd

416th

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200 20 20 20 20 20 20 20 20 20
9 10 11 12 13 14 15 16 17 18 2019

Table 25. Means in the Overall Rank 10 Top Universities – in different countries / areas in 2019 (MANOVA)

County/Area	Mean/SD	Vs European Union post Brexit – MANOVA 1,18,19 F	P
European Union post-Brexit	103.0±21.6		
Europe	57.2±27.9	16.849	<0.001
UK	95.3±66.9	0.120	0.733
USA	15.4±9.1	139.683	<0.0001
China	61.8±40.5	8.057	0.011
Asia without China	118.8±52.3	0.074	0.788
Private companies	54.6±42.1	10.463	0.005
Italy	264.0±85.11	**33.626**	<0.0001

Table 26. Means in the "Research" Rank 10 Top Universities – in different countries / areas in 2019

County/Area	Mean/SD	Vs European Union post-Brexit ANOVA 1,18,19 F	P
European Union post-Brexit	74.4±20.5	----	
Europe	39.4±17.3	17.025	<0.001
UK	63.5±42.1	0.540	0.472

USA	18.3±6.6	67.856	<0.0001
China	44.3±27.7	7.629	0.013
Asia without China	108.6±61.3	2.800	0.113
Private companies	203.8±89.9	19.694	<0.0001
Italy	184.9±73.5	20.971	<0.0001

Table 27. Trends in the Innovation Rank 10 Top Universities – in different countries / areas in 2019 (MANOVA)

County/Area	Mean/SD	Vs European Union post Brexit	P
European Union post-Brexit	260.9±35.1	----	
Europe	218.5±48.6	5.002	0.038
UK	266.7±76.1	0.048	0.829
USA	86.4±60.1	62.862	<0.0001
China	166.5±68.3	15.112	<0.001
Asia without China	188.1±50.1	14.163	<0.001
Private companies	34.8±39.8	181.535	<0.0001
Italy	365.7±20.11	67.116	<0.0001

Table 28. TRENDS in the Overall Rank 10 Top Universities /Companies – in different countries / areas in 2015-2019

County/Area	Mean/SD 2015 (N=10 if not otherwise specified)	Mean/SD 2019 (N=10 if not otherwise specified)	Vs European Union – MANOVA F (time x group)	P
European Union post-Brexit	78.8±22.8 (N=9)	102.0±22.6 (N=9)	0.951	0.333
Europe	49.2±26.6	57.2±27.9	1.210	0,275
UK	82.5±56.4	95.3±66.9	0.224	0.637
USA	13.8±7.6 (N=9)	15.4±9.1 (N=9)	0.004	0.953
China	104.4±52.5	61.8±40.5	6.840	0.011
Asia without China	84.5±46.7	118.8±52.3	2.740	0.103
Private companies	139.3±11.2 (N=8)	62.7±47.2 (N=8)	18.383	<0.0001
Italy	206.0±50.4	264.0±85.11	10.191	0.002

Table 29. TRENDS in "Research" Rank 10 Top Universities /Companies – in different countries / areas in 2015-2019

County/Area	Mean/SD 2015 (N=10 if not otherwise specified)	Mean/SD 2019 (N=10 if not otherwise specified)	Vs European Union – MANOVA F (time x group)	P
European Union post-Brexit	83.4 ±18.4 (N=9)	70.8±22.3 (N=9)	0.251	0.618
Europe	47.0±23.4	39.4±17.3	0.624	0.433
UK	71.0±47.9	63.5±42.1	0.224	0.637

USA	14.2 ±6.6 (N=9)	18.3±6.6 (N=9)	0.220	0.641
China	68.1±36.4	44.3±27.7	3.003	0.088
Asia without China	81.0±37.7	108.6.±61.3	5.354	0.024
Private companies	213.7±63.4 (N=8)	196.8±93.6 (N=8)	1.039	0. 312
Italy	175.0±43.8	184±73.5	0.919	0.341

Table 30. TRENDS in "Innovation" Rank 10 Top Universities /Companies – in different countries / areas in 2015-2019

County/Area	Mean/SD 2015 (N=10 if not otherwise specified)	Mean/SD 2019	Vs European Union – MANOVA F	P
European Union post-Brexit	76.7±30.9 (N=9)	261.0± 36.9 (N=9)	9,175	0.004
Europe	52.2±23.9	218.5±48.6	1.210	0.275
UK	101.9±67.8	266.7±76.1	6,365	0.014
USA	17.1±15.0 (N=9)	94.5± 57.8 (N=9)	0.084	0.773
China	183.4±76.4	166.5±68.3	11.550	<0.001
Asia without China	90.7±50.3	188.1±50.1	0.683	0.411
Private companies	176.3 ±127.5 (N=8)	38.8±45.5 (N=8)	49.718	<0.0001
Italy	206.0 ±50.4	365.7±20.11	5,486	0.022

V. DISCUSSIONS

This study focuses on the European Union and, by extension on Europe, as a region of first-class knowledge creation and excellence in scientific and technological production. This production is essential for achieving high-impact innovation outputs and indicates the efficiency and effectiveness of the European research systems in transforming both public and private investments into tangible and intangible assets that enable higher value-added activities. This occurs in highly competitive international environment whereby alongside some traditional competitors and partners, new state and non-state forces have emerged over the last years. Among them, it merits mentioning China and the hi-tech private companies, such as Google, Facebook and Microsoft.

There is a general (political) consensus on the need to stimulate innovation activities in Europe, as it is largely acknowledged that such activities are fundamental for ensuring sustainable economic growth, high employment rate and greater level of competitiveness of the European private and public sectors. Innovation activities are complex, multidimensional and not always easily measurable. They depend on both considerable public and private investments (in the case of the EU the target is 3% of GDP by 2020) and adequate framework conditions[9] that enable innovation to flourish accelerating the creation of new marketable products and services. The annual European Innovation Scoreboard[10] provides a comparative assessment of the research and innovation performance of the EU Member States and selected third countries, and the relative strengths and weaknesses of their research and innovation systems. It helps countries assess areas in which they need to concentrate their efforts in order to boost their innovation performance.

Bearing in a mind the heterogenous nature of innovation, for the purpose of this study, we concentrate on the innovation generated by universities and private companies selecting the ten best scientific producers, according to the SCImago database for 2019, for each one of the eight study groups. Over the period 2015-2019, the most remarkable result is the rise of the private companies and China in the overall world rank, in the research rank, but in particular in the innovation rank. In the light of Facebook/Cambridge Analytica case in 2018[11], revealing misuse of personal data for political advertising, and taking into account the China's growing authoritarianism[12], being in the lead of knowledge generation and innovation becomes of strategic importance for the European

[9] The Innovation Deals allows to avoid regulatory obstacles for innovative products and services and set the basis for innovation-friendly legislative amendments: https://ec.europa.eu/info/research-and-innovation/law-and-regulations/innovation-friendly-legislation/identifying-barriers_en
[10] https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_pt
[11] https://www.europarl.europa.eu/RegData/etudes/ATAG/2019/637952/EPRS_ATA(2019)637952_EN.pdf
[12] https://www.foreignaffairs.com/articles/china/2019-06-11/world-safe-autocracy

Union and its Member States, as it concerns not only our economic growth and employment, but ultimately the very same basis of our civic and democratic societies.

In order to tackle the innovation gap between the European Union and its main competitors, the European institutions have put forward many initiatives, among which the European Innovation Council (EIC) appears to be the most prominent. Inspired by the existing European Research Council, constitutes one of the important novelties under the next FP for Research and Innovation - Horizon Europe (2021-2027)[13]. It aims to bring the most promising ideas from laboratories to real world application and support the most innovative companies to scale up their ideas. The EIC will provide direct support to innovators through two main funding instruments, one for early stages and the other for development and market deployment. It will also introduce more applicant-friendly evaluation procedures that will enable to assess better the ideas itself rather than the way in which it has been presented. In order words, less bureaucratic troubles and further understanding of the specific needs of researchers and innovators. We call for this approach to be equally followed in the other components and pillars of Horizon Europe, as this will make it more accessible and, consequently, more impactful on the European research and innovation ecosystem.

However, the existing and forthcoming EU programmes and financial instruments will not attain their objectives if we do not manage to overcome the obstacles to the completion of a genuine European education, research and innovation area whereby students, teachers, researchers, scientific knowledge and technology circulate freely. The announced the EU's withdrawal of the UK, which is a world frontrunner for research and innovation, will have ominous consequences for both the European and the British universities. It needs to be swiftly countered by an association agreement to the FPs, following the Norwegian and the Suisse models. Bringing back UK to the European research and innovation, after the Brexit, is particularly relevant for Italy, considering the high number of EU projects in which researchers and innovators from both countries have been involved.

In the course of finalization of the discussion, the pandemic of COVID19 broke out. Although the pandemic as such is out of the scope of this study, the way in which public authorities and private companies respond to it will shape the future of science and technology over the next five-ten years. At this point of time, it is still difficult to draw clear conclusions from this global public health crisis, which is without any doubts a world-changing event. However, one of the issues that has clearly emerged since the very beginning of the outbreak, regardless the country or the region, is that decision-making authorities need to have access to independent scientific advice, based on reliable data collected and updated in real time. This conclusion appears to be evident. Still, it is not easy to

[13] https://ec.europa.eu/commission/publications/research-and-innovation-including-horizon-europe-iter-and-euratom-legal-texts-and-factsheets_en

create and ensure a proper functioning of the necessary structures and mechanisms, which also includes open access to relevant scientific publications.

In this regard, it appears appropriate to indicate some of the measures and decisions made at European level, which are promising for the near future and can help to successfully tackle the weaknesses and some of the negative trends identified in our study. Thus, on 7 of April 2020 Ministers responsible for Research and Innovation decided to support the first 10 priority actions of the first European Research Area versus Corona Action Plan[14]. It sets out key measures the Commission services and the Member States have to put in place in order to coordinate, share and jointly increase support for research and innovation, in line with the objectives and tools of the European Research Area[15].

One of the ten actions particularly of this Action Plan is greatly important for the purpose of this study. It consists of establishing the European data exchange platform for SARS-CoV-2 and coronavirus-related information exchange, connected to the European Open Science Cloud. This platform is already operational and will allow quick sharing of research data and results, which is essential to respond to the COVID-19 pandemic. Researchers should be required to provide immediate and full open access and to share research outcomes (data, models, workflows, results) as much as possible in real time. The European COVID-19 Data Platform will consist of two connected components[16]:

- SARS-CoV-2 Data Hubs that organises the flow of SARS-CoV-2 outbreak sequence data and provide comprehensive open data sharing for the European and global research communities; and
- COVID-19 Data Portal that brings together and continuously update relevant COVID-19 datasets and tools.

The setting up of this platform goes beyond the specific needs of the scientific community in relation with COVID 19 pandemic research. It will have two main complementary effects. On one hand, it will serve as a priority pilot to realise the objectives of the European Open Science Cloud

[14] https://ec.europa.eu/info/sites/info/files/research_and_innovation/research_by_area/documents/ec_rtd_era-vs-corona_0.pdf

15 The creation of a European Research Area (ERA) was proposed in 2000 by the former Commissioner Philippe Busquin. The Treaty of Lisbon (2007) recognised research and space as a shared competence. It made the completion of ERA a Treaty requirement and provided the legal basis for the adoption of legislation to implement ERA. So far, this possibility, supported by the Parliament, has not been used due to opposition from the Council. The rationale of ERA is to create a genuine single market for knowledge, research and innovation. It may happen that on the occasion of the next reform of the Treaty on the Functioning of the European Union, ERA is reinforced and enraged in a sort of common space for Education, Research and Innovation.

[16] https://www.covid19dataportal.org

(EOSC)[17], on the other, it may pave the way for the future cooperation between the European Union and the UK in the field of research and innovation, as British scientists are strongly involved in this initiative through the European Bioinformatics Institute (EBI), an academic research institute based in the UK, which is part of the European Molecular Biology Laboratory (EMBL). Established in 1994, EMBL-EBI grew out of EMBL's commitment to making biological data and information accessible to life scientists in all disciplines[18]. EMBL-EBI works in close collaboration with the ELIXIR[19], another European intergovernmental organisation with the participation of the UK, which coordinates and develops life science resources across Europe so that researchers can more easily find, analyse and share data, exchange expertise, and implement best practices.

EMBL-EBI and ELIXIR constitute relevant examples for the post-Brexit collaboration between EU and British researchers, which is essential for the Western Europe competitiveness in the field innovation and knowledge production. What will be equally important is to ensure the association of the UK to the next European research and innovation programme – Horizon Europe -, as it has been repeatedly requested by the British and European universities[20]. The same applies to other relevant European sectoral programmes, in particular, to Erasmus +, bearing in mind the important European trend to merge and mutually reinforce the European Education and Research & Innovation policies[21], while in the past (Borroso's second and Junker's mandates) the latter were much closer to the Industrial policy. This European trend is motivated by three main reasons:

- The growing importance of the Research and Innovation activities as learning and teaching tools;

[17] Announced in April 2016, European Open Science Cloud (EOSC) aims to radically change the future of research, cloud services and data technologies in Europe - affecting strategies for companies, universities and governments. EOSC, the budget of which amounts for €6.7, is a trusted digital platform for the scientific community, providing seamless access to data and interoperable services that address the whole research data cycle, from discovery and mining to storage, management, analysis and re-use across borders and scientific disciplines. Supporting the EU's policy of Open Science, EOSC is expected to give the EU a global lead in research data management and ensure that European scientists reap the full benefits of data-driven science.

[18] https://www.ebi.ac.uk

[19] https://elixir-europe.org

[20] https://era.gv.at/object/news/5141

[21] The clear illustration of this trend is that in the present College of Commissioners led Ursula von der Leyen, two separate porta-folios have been merged into one single covering Innovation, Research, Culture, Education and Youth: https://ec.europa.eu/commission/commissioners/sites/comm-cwt2019/files/commissioner_mission_letters/mission-letter-mariya-gabriel-2019_en.pdf .

- The need to strengthen the interaction of the universities with the private sector (industry and SMEs) in order to ensure proper up-skilling and re-skilling of the human capital, as an essential element of the adaptation to the fast-changing global labour markets.
- The acknowledgement of the important role Universities play in the knowledge generation and the importance of further strengthening this role, *inter alia* by an appropriate financial support, as a mean to resist to the growing power of private companies, in particular Hi-tech companies, as generators of knowledge – as demonstrated in our study.

The loss of opportunities created by leaving one of the largest communities of researchers, innovators and educators in the world would be too high. This is why the EU and the UK should accelerate the post-Brexit negotiations and reach an agreement in a timely fashion, ideally before the commencement of the Horizon Europe on 1st of January 2021. The ongoing COVID 19 crisis, which regrettably has affected in an equally dramatic way both partners, should trigger more efforts in this direction. However, a shared purpose and belief in the importance of uniting - or at least closely coordinating and aligning - our research and innovation activities is not enough to see a deal come to fruition, as there are numerous political and technical challenges to be overcome.

Beyond the biomedical research related to the COVID 19 pandemic, which ultimately should lead to an effective and an efficient prevention, diagnostics and treatment in the near future, this on-going crisis and its aftermath will have a major impact on research and innovation, and the way in which we communicate on them. Thus, the trends in the European scientific publications as well as in those of the EU's main competitors may experience some important changes over the next years.

In the EU the COVID19 outbreak occurred during the negotiations over the European budget for the period 2021-2027, the so-called multiannual financial framework (MFF). All Members States have reported cases, but the burden is asymmetrically distributed, being Italy and Spain by far the most affected countries. After the first measures adopted by the European Central Bank and the European Commission (which are clearly out of the scope of this study), what is still at stake - and will be decisive for the future - is the organisation and financing of the reconstruction phase. On 26 of April the European Council[22] agreed to work towards the establishment of an EU Recovery fund, based on a considerably increased EU budget for the next seven years. Such fund, the structure and modalities of which still need to be defined, is expected to mobilise around 1-1.5 trillion euros for the European post-pandemic economic and social recovery. In addition, there will be an important re-allocation of financial resources among the different sectoral programmes. In the case of the next European framework programme for research and innovation, it remains unknown whether it will

[22] https://www.consilium.europa.eu/en/meetings/european-council/2020/04/23/

suffer any reductions of the proposed €94.1 billion[23]. Whatever the final budget is, it appears clear that there will be a revision of the priority areas. The European Green Deal with all its specific fields will certainly concentrate considerable part of the funds. Nearly every major aspect of the European economy will have to be overhauled, from energy generation to food consumption, from transport to manufacturing and construction. Consequently, new technologies, sustainable solutions and disruptive innovation will be critical to achieve the ambitious objectives of the overarching European flagship initiative[24]. These efforts can lead to an important increase in the quantity, but also of the quality (the Impact factor), of the European scientific publications in these cross-cutting, multidisciplinary area. The EU is by far the most relevant promoter on the international arena of sustainable development and a fair ecological transition. This leading political and institutional role should also be reflected in the bibliometric and innovation indicators. In fact, among the first set of five Horizon Europe missions[25], four are directly linked with the European Green Deal. These are adaptation to climate change including societal transformation, healthy oceans, seas coastal and inland waters, climate-neutral and smart cities and soil health and food[26].

The creation of the European Innovation Council mentioned before, which from the beginning of 2021 will operate as an independent European executive agency, will be operational for improving the European innovation capacities, measured in new product and services brought to the market. It has to be pointed out that the adjustment of priorities and the possible budgetary cuts or shortfalls, provoked by the COVID 19 pandemic, will not affect Horizon Europe's rules of participation in which the need to produce scientific publications – subject to open access – from the projects funded is largely embedded. However, in certain technological areas, there might be a shift from fundamental to more applied research and technological development, which is generally less susceptible to generate scientific articles. The financial support at EU level to research and innovation is not limited to Horizon Europe budget, as many other instruments and funds, in particular, the European structural

[23] In 2019 the European Parliament proposed to increase Horizon Europe's budget to €120 billion, which in the current context appears very unlikely.

[24] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

[25] Partly inspired by the Apollo 11 mission to put a man on the moon, European research and innovation missions aim to deliver solutions to some of the greatest challenges facing our world. The concept has been developed by Mariana Mazzucato - https://ec.europa.eu/info/sites/info/files/mazzucato_report_2018.pdf - and fully integrated into the design of Horizon Europe. Missions have to be bold, inspirational and widely relevant to society. They will facilitate the European citizens' understanding of the value of investing into research and innovation

[26] The fifth one is cancer.

and investment funds[27] can support these activities, both alone or in conjunction with other public and private investments.

In the case of Italy, the evolution of the scientific publications' trend will largely depend on the way in which the pubic authorities and the private sector mange to cope with the difficult economic and social consequences of the COVID 19 pandemic crisis. In a short term, it is to be expect that the foreseeable scale down of public and private funds devoted to research and innovation worsens its position in the research and innovation ranks. However, in the middle and the long terms, an optimised use of national and European funds, accompanied by the necessary structural reforms may lead to a substantial gain of competitiveness.

Since the first EU Framework Programmes for research and innovation in the 1980s, the UK has played a central part in EU research and innovation actions. EU funding has been an integral part of the UK research and innovation landscape and many UK organisations are central actors in EU-funded projects and research and innovation networks in Europe[28]. UK Higher Education Institutions receive by far the largest share of EU funding for research and innovation in the UK, including nearly two thirds of EU Framework Programme grants so far under Horizon 2020[29], and significant support from European Regional and Development fund and European Investment Bank loans as well. UK industry also receives substantial amounts of EU funding for research and innovation. UK SMEs are among the most successful in attracting EU funding and the amounts of funding awarded to UK SMEs during FP7 is equivalent to more than 15% of R&D expenditure by SMEs in the UK. This is why the Brexit opens a period of uncertainty and potential risks for many areas of UK research and innovation, which at this point of time appears difficult to assess. In addition to the loss of funding opportunities, the withdrawal from EU programmes entails important obstacles for networking and influence on the shaping of strategic initiatives.

The United States is been heavily affected by the current crisis and will certainly re-think many strategic choices within and beyond the healthcare sector. While most of these choices will be incumbent upon the next American administration, resulting from the forthcoming Presidential

[27] The European structural and investment funds (ESIF) are: European regional development fund, European social fund, Cohesion fund, European agricultural fund for rural development, European maritime and fisheries fund .The ESIF mainly focus on five areas: research and innovation, digital technologies, supporting the low-carbon economy, sustainable management of natural resources and small businesses: https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en

[28] https://acmedsci.ac.uk/file-download/70343877

[29] https://cordis.europa.eu/projects/en

elections in November 2020[30], it is clear that disruptive innovation and emerging technologies will accelerate changes and pay the way to the next normal. Nine areas appear to be particularly prominent[31]. These are new generation robots, robotic process automation[32], 3D printing, big data and analytics, artificial intelligence, blockchain, and more specifically for the healthcare sector, cognitive devices (portable, wearable, ingestible, and/or implantable devices that can monitor health information, engage patients and their community of caregivers, and deliver therapies autonomously), electroceuticals[33] and targeted and personalized medicine. The way in which advances in these areas can be integrated will be decisive for delivering transformative change. The scientific production generated by private companies, most of them located in the United Sates, will also be devoted preferentially to these fields, and it is expected that it will continue to grow both, in quantitative and qualitative terms.

Over the past ten years China has built a large and extensive national innovation system. It covers the supply of innovation generated by research and development institutions and enterprises, the demand for innovation by enterprises, and the accumulation and allocation of resources that enable both the supply of and demand for innovation to supply the innovation and technologies required for productivity growth. The top five Chinese companies accounted for almost 30% of total research and technological development spending in China, a higher proportion than among the top five companies in the United States and the European Union (EU), where they represented less than 20 percent of total spending[34]. This indicates that in China research is more concentrated in the largest companies, controlled by the state's authorities, and the majority of enterprises may be investing relatively little in research. Apart from the negative effects on the Chinese economic growth, the COVID19 pandemic crisis has led to serious reputational problems for the Chinese authorities, due to the lack of transparency and the misinformation regarding both the origin of the epidemy and the overall crisis management. This may also damage and undermine the credibility of the Chinese researchers with potentially negative consequences for the Chinese scientific publications, more in qualitative (impact and influence) than in quantitative terms. The rest of the Asian countries could, see their scientific

[30] The result of these elections will shape the transatlantic relations over the next years and the opportunities to tackle jointly some of the global societal challenges. It will also impact on the post-Brexit agreement between the EU and the UK.

[31] https://www.mckinsey.com

[32] The automation of repetitive tasks via simple rules or heuristics has the potential to rapidly enhance productivity

[33] Small implantable devices can alter the nervous system's electrical impulses to treat a variety of diseases

[34] http://documents.worldbank.org/curated/en/833871568732137448/pdf/Innovative-China-New-Drivers-of-Growth.pdf

publications increase and improve, as they have been considerably less affected by the pandemic crisis than China and managed to put in place more efficient measures to counter its aftermath.

Beyond the specificities of each country and region, the shape of the "next normal" will be largely influence from the degree of movements from globalization, in terms in interdependence and openness, to deglobalization and regionalization with a massive restructuring of production and global supply chains. These movements will have a major incidence on the flow of information, including data sharing and scientific publications.

V. CONCLUSIONS

1. Over the period 2015-2019, the most remarkable result in the generation of scientific results and publications is the rise of private companies, working in the field of digital technologies, and China.

2. The next EU framework programme for research and innovation – Horizon Europe – together with the other programmes and financial instruments of the EU budget for the period 2021-2027 have the potential to boost the European scientific publications and to re-gain competitiveness vis-à-vis other countries, regions and private companies.

3. A robust EU research and innovation requires not only financial support, but also the right framework conditions. In this regard, the completion of a genuine European education, research and innovation area whereby students, teachers, researchers, scientific knowledge and technology circulate freely will play an important role over the next years.

4. Brexit has opened a period of uncertainty for many areas of the EU and the UK research and innovation and created potential risks for the Western Europe's competitiveness on the international arena. Reaching in due course an association agreement of the UK to Horizon Europe and other relevant EU sectoral programmes will be mutually beneficial for the European and British scientists, innovators and entrepreneurs.

5. The current COVID 19 pandemic crisis is a world-changing event with multiple far-reaching effects that will shape our way of living and working over the next five-ten years.

6. In the field of research and innovation, COVID 19 will alter the setting of priorities and the financial allocations. In the case of the EU, this may result in less resources for some areas of basic research as well as in reduction of the financial provisions for Horizon Europe and other relevant European funds and instruments.

7. Uncertain times call for trusted facts and reliable scientific information. This is why the leadership in the generation of knowledge and scientific publications is of a strategic importance not only for our economic competitiveness, but also for the protection of our fundamental rights and democratic values.

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VIII. ANNEXES

ANNEX A

Active Aging and Elderly's Quality of Life: Comparing the Impact on Literature of Projects Funded by the European Union and USA

Kirilov I., Atzeni M., Perra A., Moro D. and Carta M.G. (2017)

1. BACKGROUND

Excellence was the one of the declared goals of FP7. Its importance has been reaffirmed with reference to the on- going Horizon 2020 programme [1]. The publications produced in the scientific literature are considered as indicators of excellence by official evaluative documents of the European Commission. As regards specifically FP7 the Annual Monitoring Report 2015 on Horizon 2020 compared the publications reported by FP7 project coordinators to other publications from Member States, the World, Switzerland, United States and Japan [1]. This showed the better bibliometric performance of the publications derived from FP7.

The increases in publications is a crucial point in the light of the European innovation strategy aiming to enable innovative technologies to get faster to the market, and to reinforce the collaboration between industry and academia. This is particularly relevant in the field of psycho-social and healthcare treatments whereby the publication of results of a project is closely related to granting marketing authorisation, since psychosocial, psychotherapeutic or pharmacological treatment can pass from experimentation to generalised use only after efficacy tests have been published. Thus, publication of efficacy studies with robust methodologies and convincing results is required for the approbation of a treatment both by European Medicines Agency (EMA) in Europe and the Food and Drug Administration (FDA) in the United States.

However, some doubts have been raised about the importance given to the number and the relevance of scientific publications resulted from EU-funded research projects in comparison with other global competitors [2].

With this in mind, it would be useful to develop standardized procedures using well-known bibliometric indicators to assess the impact of projects on the scientific literature.

We attempted to do this in a preliminary study on Active Aging and Quality of Life of Elderly. We chose Active Aging and Quality of Life as research field first because we wanted to focus on a specific and limited area in considering the experimental value of the study; secondly, because this is a research topic of our group, in which we have specific research experience [3 - 6]; finally, Active

Aging is a focal point of research in Europe [7] in relationship to the impressive increase in the percentage of the elderly people in the European Union Members States. In the total population of the Union, elders are estimated to increase from 18.5% (around 95 million elderly persons) in 2014 to 28.7% (around 150 million elderly persons) in 2080 [7].

The objective of this study is to verify, by using well-known bibliometric indicators, whether European projects on Active Aging (AA) and Elderly Quality of Life (Qol) funded by the Seventh Framework Programme (FP7) have an impact on international literature comparable to that of projects funded by the NHI programs in USA, which is the world leader, for the period 1996-2016, in scientific production in the field of Medicine, Public Health, Geriatrics and Psychiatry [8].

This study aims to prepare more comprehensive analysis on the impact of EU-funded research once the on-going Horizon 2020 projects will have been completed.

All the basic current bibliometric indicators are based on citations, that is, on how many times the results of a study are reported in literature: the more a result is considered, the more frequently it is cited. Measuring the impact of a study on the international literature requires a reasonable time for the results to be published and how they become known to the scientific community. Thus, it is not possible, for the time being, to conduct this type of research on the outcome of most projects funded by Horizon 2020, many of which have not yet been completed.

2. METHODS

2.1. Design

Observational study.

2.2. Study Sample

15 projects were randomly selected from the CORDIS database with the following criteria: to be funded by FP7; to be completed by August 2017; to be approved from 1 January 2007 to 31 December 2012. The key words used for the search were “active aging”. With the same frame-time and the same key words 15 projects funded by the US NHI were selected from the NHI database. A block was built for each EU project that included all eligible NHI projects funded ± 1 year with the EU matched project. Then, the 15 US projects were randomly selected, one from each block. The selected projects were automatically excluded if found present in another block.

2.3. Variables, Search for Publications and Measure of Citations.

For each project, the number of publications found in the SCOPUS and Google databases were calculated as well as the number of papers published in journals classified as Q1 in one of the fields of the SCIMAGO ranking. For each publication and for each project, the number of citations found was calculated. For the total of the two groups (EU and US) the average number of publications in SCOPUS and Scholar Google databases, the average number of publications in Q1 classified journals, and the average number of citations will be calculated. The citation and the search for papers refer to August 2017.

A search for scientific publications for each selected project in the SCOPUS and Google Scholar databases was carried out. The search was conducted using the name of the project leader, the names of project participants and the title of the project. All project leaders were also contacted by mail with a request to confirm the result of the search and signal any possible missing publications that meet the above-mentioned criteria.

Two researchers in blind curried out the search for publications and the verification of the affiliation of a publication to a project, in case of disagreement a third researcher was called into question as an arbitrator. The affiliation of a publication to a project was easily for US project because the citation of the project is mandatory for the publications funded by; was quite more problematic in UE.

2.4. Data Analysis

The variables on numeric scales will be treated with the ANOVA one-way analysis of variance, the variables on a nominal basis with the chi square test.

2.5. Ethics

The study was carried out in agreement with the ethical principles of the Helsinki Declaration. The ethics committee of the Azienda Mista Ospedaliero Universitaria di Cagliari approves the study. All data treated in this study were already published and of public access.

3. RESULTS

Table **1** summarizes the results of the research. For all the indicators considered (number of published papers indexed in Scopus; number of papers published in scientific journals classified in the first quartile (Q1) of the Scimago ranking; mean number of citations in journals indexed in the Scopus depository; mean number of citations in journals indexed in the Google Scholar depository), no difference between the European projects and the US NHI projects has been found. The projects with no citation of their publications in the journals indexed in the Scopus depository were 5 (33.3%) in the European sample and 2 (13.3%) in the American sample; this difference did not reach statistical significance ($\chi 2$ with Yates correction = 0.83; p=0.36). The projects with no citation of their publications in the journals indexed in the Google depository were 4 (26.6%)

in the European sample and 2 (13.3%) in the American sample; this difference did not reach statistical significance ($\chi 2$ with Yates correction = 0.75; p=0.38).

Table 1. Synthesis of the results

NIH DATA BANK					HORIZON DATA BANK			
	Total of Publications	**Papers in Q1**	**N. Citations on Scopus**	**N. Citations on Scholar**	**Total of Publications**	**Papers in Q1**	**N. Citations on Scopus**	**N. Citations on Scholar**
I PROJET	2	1	0	79	6	3	198	390
II PROJET	13	10	22	349	2	1	0	0
III PROJET	9	8	18	358	7	1	34	57
IV PROJET	14	8	81	196	42	25	689	1108
V PROJET	14	13	347	684	16	6	34	77
VI PROJET	13	10	480	675	0	0	0	0
VII PROJET	3	3	8	103	0	0	0	0
VIII PROJET	4	1	14	101	1	1	380	555
IX PROJET	4	2	72	97	11	9	185	283
X PROGETTO	0	0	0	0	0	0	0	0
XI PROJET	1	1	21	42	10	1	43	92

XII PROJET	13	10	165	309	4	1	13	22
XIII PROJET	4	3	56	93	3	2	95	158
XIV PROJET	0	0	0	0	0	0	0	0
XV PROJET	12	10	92	117	12	3	116	219
	7.07 +/- 5.59	5.3 +/- 4.6	91.00+/- 140.81	213.5+/- 221.0	5.2 +/-5.3	3.5 +/-6.4	119.13+/ -190.20	207.42+/ -310.5
STAT	df 1,28,29 F=0.88 P=0.35	df 1,28,29 F=0.78 P=0.38	Df 1,28,29 F=**0.213** **P=0.648**	df= 1.28.29 F=0.004 P=0.95	–	–	–	–

4. DISCUSSION

The study has demonstrated that the results of EU-funded Active Aging projects have an impact on international scientific literature and a level of visibility comparable to that of similar projects funded in the United States by the NHI Agency.

We consider that the choice of the two depositories for the calculation of citations (Scholar and Scopus) has not produced any bias. This choice was motivated by the fact that one of them is European (Scopus), while the other one is American. The Web of Science database is also widely used in literature, but 99% of Web of Science indexed papers are also in Scopus and virtually 100% are indexed in Scholar.

The results of this study must however be considered in the light of some methodological limits. The first is the low statistical power of the study owing to the small size of the sample examined. This requires the data to be confirmed by more extensive studies, which we plan to carry out once most of the European projects funded by Horizon 2020 have been completed. Thanks to the more extensive study, we will be able to confirm or refuse the tendency towards better performance in the American sub-sample as regards almost all the indictors considered, which however in the current study does not reach statistical significance.

The second refers to the fact that in the publications derived from NHI projects it is mandatory to report the precise indication of the financing program and the official number of approval. This makes it impossible to miss a publication financed by a single project. In addition, researchers are highly motivated, and to certain extent oblige to publish, the results of their work funded by the NHI programs, in a way that if they fail to do so, this may reduce significantly the chances to receive NHI finance in the future. Moreover, we have found many European publications clearly resulting from projects funded by FP7 in which the source of funding was not mentioned. Thus, the different perception and rules regarding the scientific publications in Europe and in USA may have led to an underestimation of European publications.

The different accent put on the need to publish results and be visible for the international scientific community is also linked to the greater importance attributed by the US and to science and research, and to the stronger link between research and innovation.

Although the considerable effort made in the recent years, in particular regarding the EU budget devoted to research and innovation, the Union, as a whole, still lags behind its main international competitors. Concerning domestic spending on research measured as a percentage of GDP of the total expenditure on research by all resident companies, both public and private in a given country, we see that the European Union increased from 1.70 in 1996 to 2.04 in 2013 according to the World Data Bank [9] and from 1.67 in 2000 to 1.96 in 2015 according to OECD [10]. In contrast, in the US it was 2.44% in 1996 (data for 2013 are unavailable in the World Data Bank) [and according to OECD it increased expenditure for research from2.61% in 2000 to 2.69% in 2015 [10], while China increased from 0.57 in 1996 to 2.05 in 2013 according to the World Data Bank [9] and from 0.83 in 2000 to 2.07 in 2015 according to OECD [10]. Thus, China has also surpassed Europe as a percentage of funds for research.

In addition, investment in research and innovation are far from being homogeneous within the Union. In some countries, even among those with large number of population, such as Italy, they are surprisingly scanty, and this lowers the overall European average. Although the analysis of competitiveness indicates that surprisingly Italy maintains an acceptable level of competitiveness in research despite its low level of investments [11].

Our results on a relatively small but very impactful scientific field are consistent with data on general medical research, which indicates that European research remains at a very high level of competitiveness. According to SCIMAGO ranking, even considering the specific countries, the US is the main producer of scientific literature in the medical field; but the total number of scientific papers produced in journals indexed in the period from 1996 to 2015 summing the 27 EU states (excluding the UK) in medical sciences is 3,510,689 against 3,227,211 of the US, 930,273 of the UK, 673,105 of Japan, and 594,791 of China (Scimago 2017). It should thus be noted that in a well-supported sector such as active aging, European research was found to have an impact on literature as compared to the impact of US projects in the same field.

In this observational evaluative study, our methodology appears to be reliable and could be applied to assess the impact of more extensive research areas. However, a correct evaluative methodology focused on published papers can only be established if it becomes mandatory in Europe for publications to report the essential identification of the funding projects. This would also encourage authors to gain greater international visibility, with clear positive impacts on the Union's image.

The cost effectiveness of the projects examined, that is, the relationship between the funding for research and the scientific productivity, is out of the scope of this study, but will be analyzed in a later stage.

CONCLUSION

The EU-funded on AA and Qol Elderly projects have an impact on scientific literature comparable to projects funded in the United States by the NHI Agency.

Our results are consistent with data on general medical research, which indicates that, European research remains at a high level of competitiveness.

In this experimental study, our methodology appeared to be convincing and reliable and it could be applied to the extent of the impact of more extensive research areas.

Our research did not evaluate the relationship between funding required by research and scientific productivity.

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ANNEX B

Cost-effectiveness of US National Institute of Health and European Union FP7 Projects on Active Ageing and Elderly Quality of Life-Author's reply

Carta M.G., Atzeni M., Perra A., Mela Q., Piras M., Testa G., Orrù G. and Kirilov I.

I. INTRODUCTION

A study recently evaluated the impact on scientific literature of a sample of projects funded by the 7th European Union's Framework Program for Research and Innovation (FP7) on Active Ageing (AA) and elderly quality of life (QoL) in comparison to the same number of projects funded by the USA's National Institute of Health (NHI) [1]. The results show that the European and American projects have a similar impact in terms of a number of published articles and number of citations by published papers per single project.

This study was part of a broader one aiming to set up a methodology that allows measuring the impact of European projects funded by Horizon 2020 [2] and the subsequent EU framework programs for research and innovation. The use of bibliometric analysis to assess scientific productivity and impact is particularly relevant for the EU funding programs, in particular, in relation to the promotion of so-called open science (especially, open access to publications and scientific data) and also in relation to the importance they have in the market created innovation.

The choice of the scientific domain of AA and QoL is motivated by the fact that it has been one of the priority biomedical areas of FP7 supported with a total budget of €115 million [3].

The number of Europeans aged over 65 is expected to nearly double, from 85 million in 2008 to 151 million by 2060, and the number of those over 80 is expected to rise from 22 to 61 million in the same period. Research furthering lifelong health, active ageing and well-being will, therefore, be a cornerstone in the successful adaptation of societies to this demographic change [4].

A recent commentary on the previous study acknowledged interest in the results presented while highlighting the need to introduce costs of the evaluated projects as an independent variable in future researches [5]. The commentary suggests "The Horizon / FP7 calls to finance projects on average larger than NIH. If there were any disparities in the funds collected, this would not show an equal impact between the two shores of the Atlantic. This hypothesis must be verified" [5].

The commentary also introduced some elements that would suggest a greater impact on US publications. The authors state that the US is the world leader in terms of publications. They also recall that none of the 20 top scientific journals in Scimago ranking is European, and also the fact that, among the first 100 scientific journals of the SCIMAGO ranking, only 12 are European [6].

Moreover, recently published evidence suggests that in some countries of the European Union, the performance of scientific researchers does not have the same value for academic careers [7, 8]. In the field of psychosocial interventions, an analysis of some systematic reviews indicates a greater impact of American literature compared to that of Europe [9 - 12].

The objective of the present study is to assess the impact on scientific literature and cost-effectiveness of FP7 and NHI projects in the fields of AA and QoL, respectively.

2. METHODS

2.1. Design

Observational design.

2.2. Study Sample

Twenty projects were randomly selected from the CORDIS database in accordance with the following criteria:

I. Funded by the FP7;
II. Accepted from 1 January 2007 to 31 December 2012.
III. Concluded by 31th August 2017.

As keywords for the search, we used "active ageing" and "ageing and quality of life".

With the same criteria and keywords for the search, twenty projects funded by the US NHI were selected. A block was built for each EU project which included all eligible NHI projects funded ± 1-year with the matched EU project. Then 20 US projects were randomly selected, one from each block. The selected projects were automatically excluded when extracted.

2.3 Variables, Search for Publications and Measure of Citations

For each selected project, we determined:

1. The number of publications found in the Scopus and Google databases attributable to the project, by introducing the project title, the keywords of the project, the name of the principal investigator into the databases (Scopus and Scholar), and then verifying the correct link between each found paper and the project;
2. Using the same method and criteria, we calculated the number of papers published in journals classified in the Q1 quartile of the SCIMAGO rank for each of the two groups;
3. For each publication and for each project, we calculated the number of citations found in Scopus and Scholar Google databases;
4. For each project, we found the amount of funds allocated.

The search of articles and relative citations referred to August 2017 (for producing data comparable with the previous research).

The search of papers was carried out using the name of the principal investigator, the names of the official collaborators of the project and the title of the project. Furthermore, all principal investigators were contacted by e-mail requesting information about any ongoing publications or other publications in a journal indexed in Scopus or Scholar that we may not have found.

The search for publications and citations was carried out in the blind by two independent researchers as well as verification of the correspondence of each publication to a project. A third researcher was invited to decide, in case of disagreement.

2.4. Data Analysis

The comparison will be processed using the one-way Analysis Of Variance (ANOVA) as the variables were measured on numeric scales. Nominal data were analyzed by means of the chi-square test.

2.5. Ethics

The study was conducted according to the principles of the Helsinki Declaration. The ethics committee of the Azienda Mista Ospedaliero Universitaria di Cagliari approved the study. All results of this study will be granted open access.

3. RESULTS

Table **1** shows the results concerning all indicators in the two samples (as the mean and standard deviation in the overall sample); Table **2** shows the results of comparisons. The two groups were homogeneous in all the indicators considered in the previous research (mean number per project of articles published in journals indexed in Scopus; mean number of articles per project published in journals ranked in the first quartile of quality (Q1) in Scimago; mean number of citations per project in journals indexed in the Scopus; mean number of citations per project in journals indexed in Google) with any difference between European and US projects.

The projects for which the publications showed no citations in the journals indexed in the Scopus depository were 7 (35.0%) in the European sample and 2 (10.0%) in the American sample; this difference reaches the limit of statistical significance ($\chi 2 = 0.59$; $p=0.05$). The projects for which their publications did not show any citations in the journals indexed in the Google depository were 5 (20.0%) in the European sample and 2 (10.0%) in the American sample; this difference did not reach statistical significance ($\chi 2 = 0.15$; p=0.21).

The new indicator introduced the average budget per project showed a marked difference between the two groups. The mean budget of each project funded by the EU was 3,785,513 dollars against 315,813 dollars of each project funded by the NIH.

If we consider the total of 104 publications of the NIH project, the total of 114 publications of EU/7WP EU and the total cost of the 20 projects (NIH = $3,472,149; EU/7WP EU = Euro 44,543,630), the cost per publication is 33,380 dollars in the US and 390,733 euros in the UE).

Table 1A. Project of US NIH.

Projects found	**Budget$ $**	**N° of Papers**	**Paper sin Q1**	**Citations in Scopus**	**Citations in Scholar**
I	67586	2	1	0	79
II	120044	13	10	22	349
III	375665	9	8	18	358
IV	790162	14	8	81	196
V	365388	14	13	347	684
VI	576731	13	10	480	675
VII	213319	3	3	8	103
VIII	386231	4	1	14	101
IX	83151	4	2	72	97
X	548595	0	0	0	0
XI	3337	1	1	21	42
XII	4131	13	10	165	309
XIII	292708	4	3	56	93
XIV	255456	0	0	0	0

XV	743102	12	10	92	117
XVI	540003	7	4	908	1668
XVII	531687	1	1	27	51
XVIII	89974	4	3	72	130
XIX	62730	16	8	143	246
XX	266264	6	3	23	40

Table 1B. Projects of EU.

Budget	**N° of Papers**	**Papers in Q1**	**Citations in Scopus**	**Citations in Scholar**
€5.975.821,00	6	3	198	390
€3.320.457,00	2	1	0	0
€5.980.000	7	1	34	57
€2.820.000	42	25	689	1108
€2.450.000	16	6	34	77
€3.423.572	0	0	0	0
€399.360	0	0	0	0
€5.999.548	1	1	380	555
€5.781.957	11	9	185	283
€587.150	0	0	0	0

€800.000	10	1	43	92
€2.749.338	4	1	13	22
€2.250.000	3	2	95	158
€950.000	0	0	0	0
€1.056.427	12	3	116	219
€ 5.906.757	19	13	424	668
€ 3.484.788	0	0	0	0
€ 2.350.758	12	12	242	419
€ 2.989.877	7	3	6	27
€ 4.406.272	1	1	0	2

Table 2. Comparisons Between EU and US Projects.

–	**N° of Papers**	**Papers in Q1**	**Citations in Scopus**	**Citations in Scholar**	**Budget (Dollars)**
US Projects	7.00±5.44	4.95±4.17	127.45±221.16	266.9±384.36	315,813.2±242,656.54
EU Projects	7.65±9.95	4.10±4.30	122.95±175.82	203.85±294,72	3,785,513±2308876.84
F(1, 38,39)	0.066	0.403	0.005	0.339	**44.673**
P	0.799	0.529	0.944	0.564	**<0.0001**

4. DISCUSSION

The study confirms the results of the previous one, namely the fact that the number of publications and the number of citations per project on active ageing are similar between projects funded by the

NHI in the United States and those funded by the FP7 in Europe. However, when it comes to cost-effectiveness, it results that European projects have a cost ten times higher than the Americans ones.

Owing to the size of the sample, these results should be taken with caution and considered mainly as a stimulus to go further into this research, including other indicators, and also extending it to other priority scientific areas.

Interpretation of results must be done in the light of the specificities of each program. Thus, the American programs appear to be more basic research-oriented, while the European ones are more focused on applied research and turning scientific results into innovative marketable products and services [13, 14]. On the other hand, without the presence of solid results, the European Medicines Agency (EMA) in Europe and the Food and Drug Administration (FDA) in the US [15] cannot approve innovative treatments or technologies. Therefore, the objectives of supporting market competitiveness is strictly linked, if it does not coincide, with the aim of publishing a lot and with a strong impact on literature (ie attracting many citations). But in addition to needing a minimum of published evidence to file for patents or market, the more treatment is supported by scientifically robust published evidence, the more competitive it will be.

However, the modus operandi and rules of participation in both programmes are different. In the case of EU programs, the standard implementation mode is collaborative research that requires participants from at least three different countries, among EU Member states and associated countries. Moreover, the EU programs are not intended to replace national ones, but rather to support the achievement of political objectives, mainly completion of the European research area inspired by the European single market, in which researchers, scientific knowledge and technology circulate freely (as stated in Title XIX of the Treaty on the Functioning of the European Union).

In terms of expenditure on research and innovation (R&I), Europe still lags behind its main competitors. Thus, in 2015, in accordance with the OECD, Europe sent 1.96% of its GDP against 2.07% in China and 2.69% in the US. In the case of China, there has been a 60% growth in R&I expenditure from 2000 to 2015, while in Europe, the growth was only 15% [16, 17]. It would be worth mentioning that achieving 3% of the EU's GDP invested in R&I is one of the targets of the Europe 2020.

Regarding scientific publications, the European Union, considered as the sum of its member states, maintains its excellence of production, both in terms of quality and quantity. Nevertheless, the European countries have been losing positions, in particular in some emerging scientific areas, including the biomedical. In 2017, only Germany, Italy and Poland maintained their SCIMAGO ranking for scientific production which they achieved 10 years ago (fourth, eighth and eighteenth), while others, such as France, Spain, the Netherland, Sweden, Belgium and Austria have stepped down in this ranking [1]. In addition, the number of research centers in the world in the top 100 dropped from 14 in Europe to only 10 in 2018 [1].

CONCLUSION

Our study shows lower cost-effectiveness of the FP7 European projects compared to the American NIH on active aging. This poorer outcome was found only in relation to cost of the researchers at the equal impact on scientific literature.

The differences between the EU and the US research and innovation landscape and policies may be a determinant on the difference in the costs of projects.

However, the results of this research, albeit with the limits already outlined, will have to be taken into consideration in the evaluative research of the future.

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