

Impact of R&D expenditures on research publications, patents and high-tech exports among european countries

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Abstract. – **OBJECTIVES:** This study aimed to compare the impact of Research&Development (R&D) expenditures on research publications, patents and high-tech exports among European countries.

MATERIALS AND METHODS: In this study, 47 European countries were included. The information regarding European countries, their per capita Gross Domestic Product (GDP), R&D spending, number of universities, indexed scientific journals, high technology exports and number of patents were collected. We recorded the total number of research documents in various science and social sciences subjects during the period 1996-2011. The main source for information was World Bank, Web of Science, Thomson Reuters and SCImago/Scopus.

RESULTS: The mean GDP per capita for all the European countries is 23372.64 ± 3588.42 US\$, yearly per capita spending on R&D 1.14 ± 0.13 US\$, number of universities 48.17 ± 10.26 , mean number of Institute of Scientific Information (ISI) indexed journal per country 90.72 ± 38.47 , high technology exports 12.86 ± 1.59 and number of patent applications 61504.23 ± 22961.85 . The mean of research documents published in various science and social science subjects among all the European countries during the period 1996-2011 is 213405.70 ± 56493.04 . Spending on R&D, number of universities, indexed journals, high technology exports and number of patents have a positive correlation with number of published documents in various science and social science subjects. We found a positive correlation between patent application and high-tech exports. However, there was no association between GDP per capita and research outcomes.

CONCLUSIONS: It is concluded that, the most important contributing factors towards a knowledge based economy are spending on R&D, number of universities, scientific indexed journals and research publications, which in turn give a boost to patents, high technology exports and ultimately GDP.

Key Words:

Research, R&D expenditure, Patents, High-Tech exports, Europe.

Introduction

Research in science, social science sectors and innovative activities are essential to improve the performance and are the main driving forces of the growth process in advanced economies. The research innovation in science offers multidirectional solution to overcome the challenges and contribute to improving the living standards and quality of life. Expenditures in research is important for the progress in science and technology as well as for social and economic development¹. To recognize and quantify the progress of research, bibliometric indicators are essential tools to understand the size, growth and global spread of research. These indicators are mainly based on the number of scientific research documents published². Science and technology cannot exist if researchers do not evidence or publish their experimental findings and results. Scientific writing and its outcome in the form of research publication are essential components of academic excellence. Scientific publications are a key indicator of the development of a country, and a healthy scientific research environment is a prerequisite for scientific and economic progress³.

The research information seeking behavior is essential in economic success of a country⁴. In order to achieve long-term and sustainable economic growth, spending on education, research and development is essential to produce a substantial amount of innovative research. There is a direct relationship between research and the overall development of nations as well as individual countries. This study aimed to compare the impact of

Research&Development (R&D) expenditures on research publications, patents and high-tech exports among European countries.

Materials and Methods

This observational work was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia. In this study, we reviewed all the European countries⁵. The countries who published less than 100 publications *per annum* during the period 1996-2011 were excluded. Finally, for this study, we included 47 European countries. The information regarding all the European countries, their average GDP (Gross Domestic Product) per capita for the last five years, spending on R&D, high technology exports and patents were collected from the World Bank sources⁶, and the data about number of universities were collected from the World Association of Universities⁷. The information regarding scientific journals which are indexed in Institute of Scientific Information (ISI) was obtained from Web of Science, Institute of Scientific Information (ISI) Journal Citation Reports (Thomson Reuters)⁸. Research documents in science and social science subjects during the period 1996-2011 were recorded from SCImago/Scopus⁹. For ISI indexed journals, we logged on to Web of Science, the territory was selected, country name was entered, and the names of journals along with impact factors for each European country were retrieved. For the recording of bibliometric indicators, research outcome in all world scientific journals indexed in Scopus was recorded. In SCImago site, region and country was selected, subject field "Science" and "Social Sciences" were selected and detailed information regarding the bibliometric indicators including total number of research papers (documents), citations per document and H-index in science and social science subjects among European countries were obtained.

Statistical Analysis

The data were analyzed by using Statistical Package for the Social Sciences (SPSS) software version 18 (Chicago, IL, USA). Data were expressed as Mean \pm Standard Error of Mean (SEM). The Pearson correlation coefficient was calculated to find the strength of relation between different variables. *p*-value < 0.05 was considered significant.

Results

The total number of European countries included in this study is 47, the mean GDP per capita for all the European countries is 23372.64 ± 3588.42 US\$. The yearly per capita spending on R&D 1.14 ± 0.13 US\$, number of universities 48.17 ± 10.15 , mean number of ISI indexed journal per country 90.72 ± 38.47 (Table I) high technology exports 12.86 ± 1.59 and number of patents are 61504.23 ± 22961.85 (Table II). The number of documents published in various science and social sciences subjects among the European countries during the period 1996-2011 is 213405.70 ± 56493.04 .

Table III demonstrates the Pearson correlation coefficient between the mean GDP per capita, spending on R&D, number of universities, indexed journals and total number of research documents in various science and social sciences subjects among European countries during the period 1996-2011. We found that spending on R&D ($r = 0.426$; $p = 0.003$) [Tables I, II Figure 2]; number of universities ($r = 0.799$; $p = 0.0001$) [Tables I, II Figure 3]; indexed journals ($r = 0.793$; $p = 0.0001$) [Tables I, II Figure 4]; high technology exports ($r = 0.289$; $p = 0.0001$) [Table II, Figure 5]; and number of patents ($r = 0.739$; $p = 0.0001$) [Table II, Figure 6]; have a positive correlation with number of published documents in various science and social science subjects. However, there was no association between the GDP per capita and research documents ($r = 0.123$; $p = 0.411$) [Tables I, II Figure 7]. In addition, the present study results also shows that there was a positive correlation with spending on R&D and number of patent applications ($r = 0.320$; $p = 0.030$), high technology exports ($r = 0.377$; $p = 0.013$) (Table III); universities and patent applications ($r = 0.870$; $p = 0.0001$), high technology exports ($r = 0.058$; $p = 0.712$) (Table III); ISI Indexed journals and patent applications ($r = 0.584$; $p = 0.0001$), high technology exports ($r = 0.137$; $p = 0.383$) (Table III). However, GDP was significantly correlated with high technology exports ($r = 0.414$; $p = 0.006$) (Table III). Furthermore, we found a correlation between patents and high technology exports ($r = 0.230$; $p = 0.029$).

Discussion

In this study, we compare the impact of R&D expenditures, number of universities and science

Table I. European countries with their per capita GDP, spending on R&D as % of total GDP, number of universities and scientific indexed journals.

Countries	GDP in US\$	Spending on R&D	Universities	Journals
Albania	2274.923	0.12	15	0
Armenia	1625.382	0.22	12	3
Austria	35056.57	2.22	43	34
Azerbaijan	2330.475	0.29	26	1
Belarus	3025.676	0.73	36	3
Belgium	33388.15	1.90	44	21
Bosnia & Herzegovina	2686.27	0.02	15	4
Bulgaria	3558.424	0.50	36	10
Croatia	9125.598	0.90	7	36
Cyprus	20785.47	0.34	15	0
Czech Republic	11815.15	1.28	28	33
Denmark	43743.98	2.41	31	81
Estonia	9202.864	0.90	10	3
Faroe Islands	34149.72	0.86	1	0
Finland	34540.67	3.34	31	14
France	31419.21	2.17	261	192
Georgia	1495.214	0.26	13	1
Germany	32430.27	2.47	281	557
Greece	19215.27	0.56	50	17
Greenland	24687.96	0.59	1	0
Hungary	8968.525	0.88	37	31
Iceland	39950.16	2.60	10	3
Ireland	39182.74	1.27	24	27
Italy	27772.76	1.10	91	125
Latvia	6891.935	0.47	22	2
Liechtenstein	96906.97		2	0
Lithuania	6987.143	0.67	17	19
Luxembourg	73675.8	1.62	2	0
Macedonia	2936.69	0.29	9	2
Malta	14256.08	0.49	3	0
Moldova	880.1018	0.53	12	1
Monaco	112795.8	0.04	1	0
Montenegro	4382.008	1.03	1	0
Netherlands	36025.11	1.87	36	665
Norway	59023.41	1.63	23	29
Poland	7679.39	0.61	131	126
Portugal	16603.15	0.87	62	6
Romania	4326.413	0.47	62	47
Russian Federation	5452.284	1.10	305	146
Serbia	3571.394	0.64	13	18
Slovakia	10317.78	0.63	33	19
Slovenia	16589.81	1.45	4	11
Spain	22944.57	1.04	79	78
Sweden	38324.69	3.65	37	18
Switzerland	51339.09	2.77	48	180
Ukraine	1767.062	1.01	76	17
United Kingdom	32405.72	1.78	168	1637
Mean	23372.64	1.14	48.17	89.72
SEM	3588.42	0.13	10.15	38.47

Main sources of retrieving information⁶⁻⁸, Data expressed as Mean ± SEM.

journals on research publications, patents and high-tech exports among European countries. We found a positive correlation between the spending on R&D, number of universities, indexed

journals, high technology exports and patents on total number of research documents in various science and social science subjects in European countries. However, we did not find an associa-

Table II. European countries with total number of research documents and patents.

Countries	Research documents	Patents	High Tech Exports
Albania	1229	1505	1.595375
Armenia	8054	2399	2.707653
Austria	188440	36529	12.87874
Azerbaijan	6135	696	4.449963
Belarus	22334	21051	3.304976
Belgium	265913	11847	9.181968
Bosnia &Herzegovina	3524	2157	2.498837
Bulgaria	40848	9377	4.758113
Croatia	49462	10395	9.759115
Cyprus	8427	315	13.34961
Czech Republic	142090	9872	11.76922
Denmark	183880	57421	19.03193
Estonia	16573	5042	12.27325
Faroe Islands	287	0	0.696235
Finland	170476	34947	20.61306
France	1141005	252788	21.4637
Georgia	6381	6388	16.03469
Germany	1581429	886022	16.10399
Greece	160760	7061	10.00937
Greenland	507	0	20.04515
Hungary	100137	38310	22.92828
Iceland	9285	5758	24.94254
Ireland	91125	14588	37.16318
Italy	851692	54692	7.924204
Latvia	8396	3087	5.467662
Liechtenstein	684	0	–
Lithuania	21098	1972	6.233325
Luxembourg	5121	1381	12.00611
Macedonia	4401	2315	1.448676
Malta	2029	2049	57.86051
Moldova	4032	4333	6.116833
Monaco	1049	249	–
Montenegro	721	1076	–
Netherlands	487784	39512	28.04445
Norway	141143	84985	16.31046
Poland	304003	79463	3.64547
Portugal	117469	3799	6.47468
Romania	76361	21614	4.679533
Russian Federation	527442	498911	11.47549
Serbia	21011	4680	–
Slovakia	49863	16797	4.813
Slovenia	44142	5964	5.229677
Spain	665977	48688	6.919867
Sweden	337135	57036	16.87223
Switzerland	350253	35490	22.45978
Ukraine	98083	86237	4.643543
United Kingdom	1711878	421901	26.9064
Mean	213405.70	61504.23	12.86
SEM	56493.04	22961.85	1.59

tion between GDP per capita and research outcomes (Table III). To the best of our knowledge this is the first study to evaluate the impact of such promising factors on research outcomes, patents and high technology exports among European countries.

GDP is the economic growth measured in terms of an increase in the size of country economy. It is the main indicator used to gauge the strength of a country's economy and represents the total value of all goods and services produced over a specific time period. We found no correla-

Table III. Pearson correlation coefficient between GDP per capita, spending on R&D as % of total GDP, number of universities, indexed journals, high technology exports, patents and total number of research documents in various science and social sciences subjects among European countries during the period 1996-2011.

Parameters	Research documents
GDP per capita US\$	$r = 0.123$ $p = 0.411$
Spending on R&D	$r = 0.426$ $p = 0.003$
Universities	$r = 0.799$ $p = 0.0001$
Indexed journals	$r = 0.793$ $p = 0.0001$
Number of patent applications	$r = 0.739$ $p = 0.0001$
High technology exports	$r = 0.289$ $p = 0.0001$

tion between GDP per capita and total number of documents in various science and social science subjects (Table III, Figure 6). The top three European countries with the highest GDP are Monaco (112795.8), Liechtenstein (96906.97) and Luxembourg (73675.801) and the countries with the lowest GDP are Moldova (880.10), Georgia (1495.214) Armenia (1625.38) (Table I). We found that there is no difference in the research outcomes between the countries with high GDP compared to the countries with a low GDP. These findings show that, the research outcome does not depend upon GDP, but it actually depends on how much percentage of total GDP is being spent on R&D.

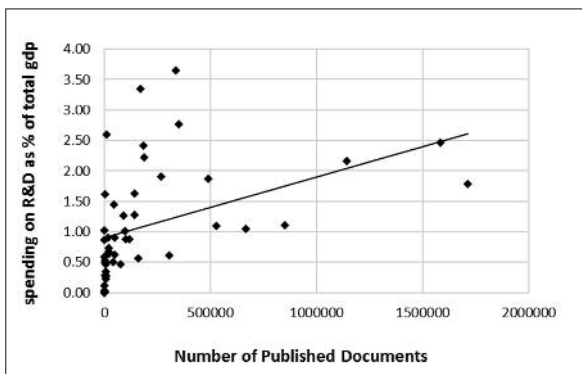


Figure 1. Correlation coefficient between spending on R&D and total number of research documents in various science and social science subjects among European countries during the period 1996-2011.

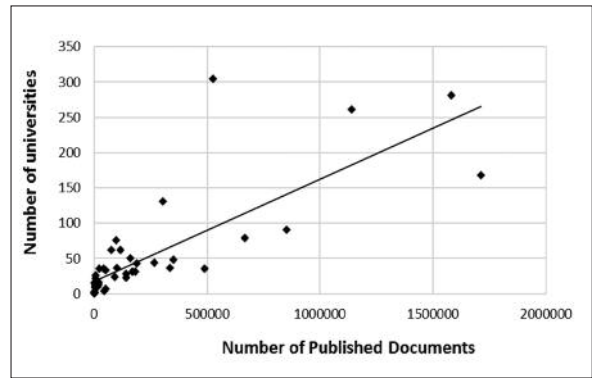


Figure 2. Correlation coefficient between the number of universities and total number of published research documents in various science and social science subjects among European countries during the period 1996-2011.

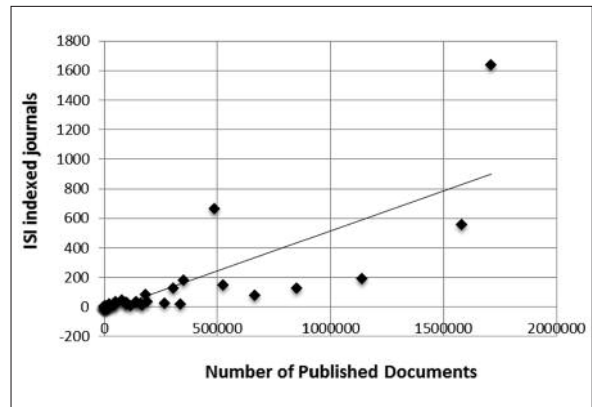


Figure 3. Correlation coefficient between scientific indexed journals and total number of research documents in various science and social science subjects among European countries during the period 1996-2011.

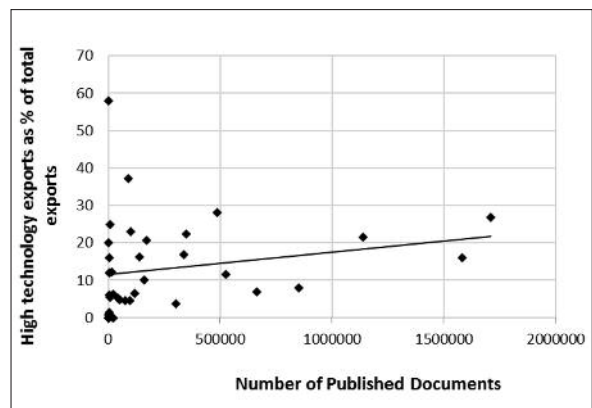


Figure 4. Correlation coefficient between high technology exports and total number of research documents in various science and social science subjects among European countries during the period 1996-2011.

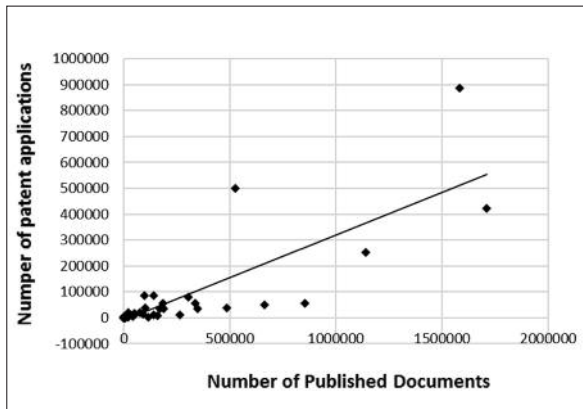


Figure 5. Correlation coefficient between number of patents and total number of research documents in various science and social science subjects among European countries during the period 1996-2011.

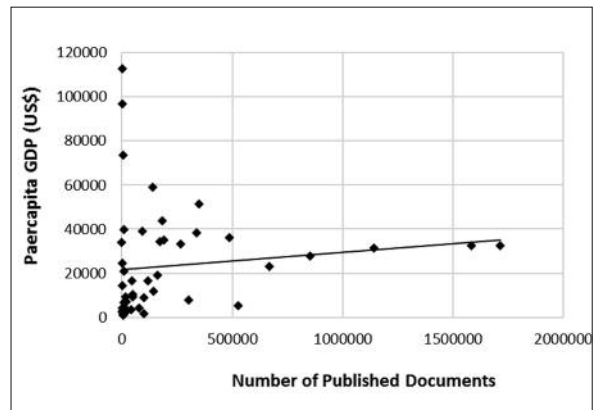


Figure 6. Association between per capita GDP and total number of research documents published in various science and social sciences subjects among European countries during the period 1996-2011.

The investment in R&D is a major factor in determining the contribution that research can make to scientific progress and innovation. The investment in R&D is associated with high rates of research outcomes. The national innovative capacity is highly dependent on R&D investment. The European countries who are spending more on R&D are Germany, France and United Kingdom. These countries are spending more on

R&D and generating more in research outcomes (Figure 7).

Zhang¹⁰ conducted a study on the research relationship between expenditure for science and technology activities and economic growth and reported that R&D input adds great contribution in the economic growth development. The R&D efforts provide better opportunities to create new knowledge and enhance capabilities to integrate

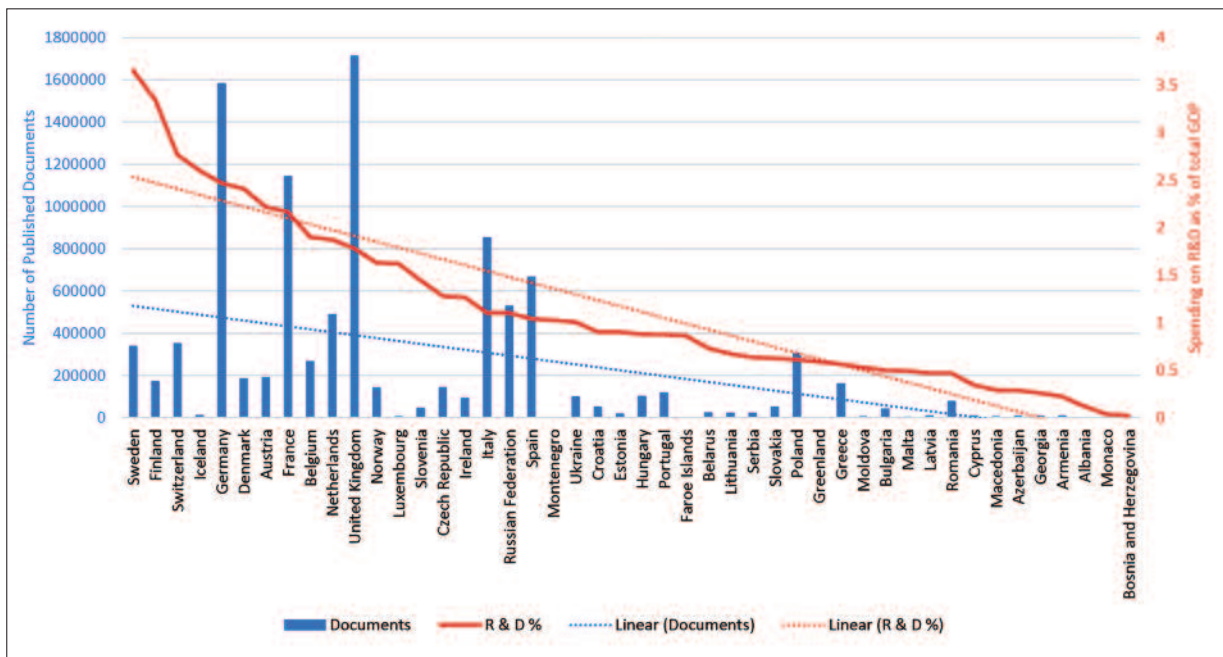


Figure 7. The trend among European countries on spending on R&D and published documents.

and exploit external knowledge. Therefore, investing greater amount on R&D generate strong research and technological based capabilities in terms of their processes and product innovations and enhances overall performance.

Helpenny et al¹¹ conducted a study to examine the origin of publications and link between the percentages of GDP spent on R&D. They found that the percentage of GDP spent on R&D was positively correlated with the number of publications ($r = 0.603, p < .001$).

Meo et al¹² reported that the Asian countries who spend more on R&D have a large number of universities and scientific indexed journals produced more in research outcomes including total number of research publication in various science and social science subjects. They also found that spending on R&D, number of universities and indexed journals have a positive correlation with number of published documents in various science and social science subjects. In another study of Meo et al¹³, they found similar types of findings in Middle East countries. Similarly, in the present study, we found a positive correlation between the spending on R&D and research outcomes in various science and social science subjects among European countries. Our study findings are in agreement with the results of Helpenny et al¹¹, Meo et al¹² and Meo et al¹³.

In European countries, the number of universities and research institutions are satisfactory enough the mean number of universities in European countries is 48.17 ± 10.15 . In the present study we found a positive correlation between the number of universities and research publication in science and social science subjects among the European countries (Tables III, IV, Figure 3).

Choung and Hwang¹⁴ reported that universities play an important role in increasing number of research papers in the ISI database and the related research activities of the universities supported the development of industrial technologies. Similarly, in the present study we found a positive association between number of universities and an increasing number of ISI research papers. This is an established fact that the basic place of the research is the universities, we believe, European countries further increase the number of universities and eventually the research outcome will further enhance.

The countries in Europe having a large number of ISI indexed journals are: United Kingdom 1637, Netherland 665, Germany 557, France

192, Switzerland 180. The mean number of journals in the all the European countries is 89.72 ± 38.47 (Table I). In some European countries the scientific journals especially the ISI indexed journals are less in number such as Albania, Cyprus, Greenland, Malta and Monaco. Many do not have on-line access, and are not indexed in major bibliographic/citation databases. The majority of indexed journals, however, do not have a stable presence in popular scientific databases. The total number of ISI indexed journal in European countries is 4181 (Table I), we found a positive correlation between the number of scientific journals and research documents; it shows that countries having more ISI Indexed journals are producing more research papers (Tables III, IV, Figure 4).

In addition to reviewing GDP, spending on R&D, number of universities, and ISI Indexing and their association with research outcome, we also reviewed the patents and high tech exports in European countries.

The R&D and patents relationship has attracted enormous attention in the scientific literature. The reason is a powerful one as innovative activity is essential to improve the performance and is the main driving force of the growth process in advanced economies. Patents promote knowledge by patented invention placed in the public domain in return for the exclusive right to exploit the invention. Patents play an important role in technology transfer from public to private sectors and are associated with an enhance in

Table IV. Pearson correlation coefficient between GDP per capita, spending on R&D as % of total GDP, number of universities, indexed journals, high technology exports, patents and total number of research documents in various science and social sciences subjects among European countries during the period 1996-2011.

Parameters	Patent applications	High Technology Exports
GDP per capita US\$	$r = 0.040$ $p = 0.791$	$r = 0.414$ $p = 0.006$
Spending on R&D	$r = 0.320$ $p = 0.030$	$r = 0.377$ $p = 0.013$
Universities	$r = 0.970$ $p = 0.0001$	$r = 0.058$ $p = 0.712$
Indexed journals	$r = 0.584$ $p = 0.001$	$r = 0.137$ $p = 0.383$
Patents versus high technology exports	$r = 0.230$ $p = 0.029$	

knowledge¹⁵. Studies on the R&D-patent relationship were conducted and lead to the conclusion that there is a significant correlation between R&D inputs and patent counts¹⁶. Similarly, we found an association between spending on R&D and increased number of patents in European countries. Moreover, we observed that there is a positive association between patents and high technology exports (Table IV).

Study Strengths and Limitations

In this report we selected the large number of European countries, employed all the promising parameters to compare the research outcomes which play potential role in the development of research such as GDP, spending on R&D, number of universities, ISI-Indexed Journals, high technology exports and patents. We collected the information regarding the European countries, their GDP, spending on R&D, from very reliable source of the World Bank. The data about number of universities were gained from the World Association of Universities. The information regarding the ISI-indexed scientific journals and bibliometric indicators in various science and social sciences subjects were obtained from the Institute of Scientific Information (ISI), Web of Science, Journal Citation Reports (Thomson Reuters), and SCI-imago web. These are highly reliable sources in scientific literature. However, it may be possible that, occasionally the citation count tools may mis-cite a paper, and there are chances of same paper may appear twice with slightly different details. This may inflate the number of citation counts.

Conclusions

This is the first study which has analyzed the productivity of research papers, patent applications and high technology exports in European countries. We found that spending on R&D, number of universities and scientific indexed journals, high technology exports and patents have a positive association with the total number of research documents in various science and social science subjects. However, we did not find an association between the GDP per capita and research outcomes. It shows that the European countries who are spending more on R&D, have more universities and ISI indexed journals are producing more research papers, patents and ultimately generating high technology exports.

We observed that the most important contributing factors towards a knowledge based economy are spending on R&D, number of universities, scientific indexed journals and research publications, which in turn give a boost to patents, high technology exports and ultimately GDP. It is suggested that continuing efforts must be taken to further enhance the policy to promote research culture. These steps will increase the research oriented education and culture and ultimately the research outcome will increase and bring the scientific, social as well as economic development in the European region.

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Conflict of Interest

The Authors declare that there are no conflicts of interest.

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