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Factors that Impact Countries' Innovation in Computer Science Research Publications

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Abstract

This paper has four primary goals. First, to examine the number of Computer Science documents published from of 1996 to 2017, which has shown the rise and fall of some countries. Second, to examine differences between countries, using a gap analysis, to enable a country classification to be introduced according to each country's' computer science documents published in 2017. Third, the study sought to examine the factors affecting the number of computer science documents published in 2017. Fourth, this paper discusses China and India's means and methods to increase their computer science publication reflected in eight methods and means.

Keywords: Computer Science, Scopus, China, India, government, Scientometric Indicators.

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Factores que afectan la innovación de los países en publicaciones de investigación en informática

Resumen

Este documento tiene cuatro objetivos principales. Primero, examinar el número de documentos de Ciencias de la Computación publicados de 1996 a 2017, que han mostrado el ascenso y la caída de algunos países. En segundo lugar, para examinar las diferencias entre países, utilizando un análisis de brechas, para permitir la introducción de una clasificación de país de acuerdo con los documentos informáticos de cada país publicados en 2017. Tercero, el estudio buscó examinar los factores que afectan el número de documentos informáticos publicados en 2017. Cuarto, este documento discute los medios y métodos de China e India para aumentar su publicación en informática reflejada en ocho métodos y medios.

Palabras clave: Informática, Scopus, China, India, gobierno, Indicadores cienciométricos.

1. INTRODUCTION

The progress of nations is measured by the knowledge that they create and the benefit they make to of all mankind. While tacit knowledge is embedded in the human mind, explicit knowledge is measured by literature and the written word. Currently, the written word of knowledge is evaluated, assessed, and gauged by many levels of honest reviewers that allow publications. The review of literature is a process that is conducted by many organizations, such as Scopus, the Web of Science, and publishing houses, such as Springer, IEEE, and ACM. The value of any research paper is reflected by the number of citations, hence the value of knowledge embedded in the research paper.

The knowledge explicated in any research paper is the creation of a human being dubbed as the researcher, author, or scientist. Humans are affected by many factors when being creative, countries and nations try to provide their best means so that creative humans can excel and shine in producing their best innovative work. This paper examines the impact of GDP(PPP), Population, Internet Users, Number of Universities, Education Expenditures (% of GDP), and Research, and Development Expenditure (% of GDP) on the production of Computer Science Research publications. This paper attempts to discover which of the previous elements affect a nation's most innovative work. This paper also suggests a classification of countries in accordance with the country's published research in computer science. The classification resulted in having 8 levels while level 3 had 2 sub-levels, level 6 had 4 sub-levels, and level 7 had 4 levels. Furthermore, the paper examines the case of China and India's means and methods of rising in terms of research in the Computer Science field.

2. METHODOLOGY

This study included 104 countries. The information collected about the 104 countries included their GDP(PPP), Population, Internet Users, Number of Universities, Education Expenditures (% of GDP), and Research and Development Expenditure (% of GDP). The biblio-metric indicators, including the total number of Computer Science research documents published during the period of 1996 to 2017 was recorded. The main sources for the collected data were the World Bank and SCImago/Scopus (scimagojr, 2019).

3. RESULTS

This section will present the findings of this study. By examining the number of computer science publications over the years, the rise and fall of some countries' rankings were noticed and examined. A classification was suggested according to computer science documents published in 2017. This study examined the factors affecting the number of computer science documents published in 2017 and discussed six factors relating to the rise and fall in rank of various countries, which included: GDP(PPP), Population, Internet Users, Number of Universities, Education Expenditures (% of GDP), and Research & Development expenditure (% of GDP), and their correlation to the number of computer science documents published in 2017. The paper also examined China and India's means and methods to increase their ranks, which is reflected in seven methods and means: Laws and Regulations, Education, Economy, Knowledge transfer, Planning, Growing R&D Workforce, and Private and Public investment.

This study was conducted on 104 countries listed in the years 1996 to 2017 in Scopus. The researchers examined the rise and fall in Document Publishing rank of different countries. First, the researchers examined the countries that rose in rank, (39 countries), and then they examined the countries that went down in rank (59 countries). Additional review was done on the countries that stayed at the same level over the study years (6 countries). The idea is explained further in the next paragraphs and in Figure 1.

Figure 1: Rise and fall of the countries according to rank

Out of 104 countries studied, 39 countries rose in rank. They are: China, India, South Korea, Spain, Malaysia, Brazil, Iran, Turkey, Singapore, Indonesia, Portugal, Saudi Arabia, Pakistan, Tunisia, Thailand, Romania, Morocco, Algeria, Bangladesh, Viet Nam, Colombia, United Arab Emirates, Serbia, Iraq, Philippines, Luxembourg, Lebanon, Macao, Kazakhstan, Sri Lanka, Peru, Macedonia, Oman, Bosnia and Herzegovina, Malta, Ethiopia, Palestine, Costa Rica, and Cameroon.

Out of the 104 countries studied, 59 countries dropped in rank. They are: United States, United Kingdom, Japan, France, Canada, Russian Federation, Australia, Taiwan, Netherlands, Poland, Sweden, Switzerland, Hong Kong, Austria, Greece, Belgium, Finland, Czech Republic, Israel, Denmark, Ukraine, Norway, South Africa, Egypt, Ireland, New Zealand, Chile, Hungary, Slovakia, Argentina, Jordan, Croatia, Slovenia, Cyprus, Nigeria, Bulgaria, Estonia, Lithuania, Latvia, Kuwait, Iceland, Belarus, Venezuela, Cuba, Azerbaijan, Kenya, Ghana, Libya, Puerto Rico, Georgia, Brunei Darussalam, Armenia, Bahrain, Tanzania, Mauritius, Botswana, Moldova, Zimbabwe, Uzbekistan.

Six out of the 104 countries kept their ranks, and these were: Germany, Italy, Mexico, Uruguay, Trinidad & Tobago, and the Syrian Arab Republic.

To further explain the model, according to the p-Value in Table 1.C is the factor of “Education Expenditures (% of GDP)” with a p-value of 0.898623. The next factor is “Internet Users” with p-value (0.360291), then “Population” is the most influential factor with p-value (0.278367), next is the “Number of Universities.” Next is “Research and Development Expenditure (% of GDP)” factor. The last factor is GDP(PPP) with a p-value of 1.08E-24. In reviewing the coefficients of the factors, the following was noticed. There were negative Coefficients of both “Number of Universities” and “Internet Users,” both factors may reflect the dispersion of efforts in the academic arena. Education Expenditures (% of GDP) had a high coefficient of 67.93009236. Also, the “Population” factor had a high coefficient of 2.63034E-06 in comparison with the “GDP(PPP)” factor was 3.90912E-09.

Table 1. A: Regression. Statistics

Multiple R	0.983682
R Square	0.96763
Adjusted R Square	0.965627
Standard Error	1976.645
Observations	104

Table 1.B: Regression ANOVA

	df	SS	MS	F	Significance F
Regression	6	1.13E+10	1.89E+09	483.262	6.47E-70
Residual	97	3.79E+08	3907126		
Total	103	1.17E+10			

Table 1.C: Regression: Coefficients, Standard Error, t Stat, P-value, Lower and Upper 95%.

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-260.736	529.1769	-0.49272	0.623325	-1311.01	789.5342
GDP(PPP)	3.77E-09	2.72E-10	13.83911	1.08E-24	3.23E-09	4.31E-09
Internet Users	-1.4E-05	1.55E-05	-0.91916	0.360291	-4.5E-05	1.66E-05
Education Expenditures (% of GDP)	-12.3481	96.66938	-0.12774	0.898623	-204.21	179.5139
Population	5.48E-	5.02E-06	1.090	0.278	-4.5E-	1.54E-

	06		106	367	06	05
Number of Universities	-2.91826	0.818805	-3.56405	0.000569	-4.54336	-1.29316
Research and development expenditure (% of GDP)	1038.226	227.2964	4.567718	1.45E-05	587.1053	1489.346

Number of Published Documents =	-260.736	+	3.77E-09	GDP(PPP)	+	-1.4E-05	* Internet Users	…(1)
		+	-12.3481	Education Expenditures	+	5.48E-06	* Population	
		+	-2.91826	Number of Universities	+	1038.226	Research & Development Expenditure (% of GDP)	

There is an obvious gap in the number of publications. As each country's Computer Science publications were examining, the number of publications required the researchers to create a classification of countries. The suggested classification was an 8-level classification system based on a country's number of Computer Science publications. Such suggestions showed the gap among the countries. For example, a country with publications of 70,000 is nowhere near a country with publications of only 29,000, hence the need for a classification system, which is reflected in Table 2.

Falling under the first class are China and the USA, both countries published more than 60,000 documents. China published

79,507 documents while the USA published 63,351 documents with a difference of almost 13,000 documents in favor of China. Class two, with almost 34,000 documents, is led by India with 29,051 published documents followed by Germany with 20,005 published documents. The third country in this class is the UK with 18,849 published documents.

The third class included: Japan, France, Italy, South Korea, Canada and Spain who published 15,731, 15,048, 13,285, 11,067, 11,058, and 10,474 documents, respectively. Both Japan and France were in the same range, while South Korea and Canada were in the same range.

The fourth class had Russian Federation, Australia, Taiwan, Malaysia, Brazil, Netherlands, Iran, and Poland. The fourth class has all countries with 5,000 to less than 9,000 computer science published documents. The publication counts were Russian Federation 8,701, Australia 8,547, Taiwan 7,488, Malaysia 6,927, Brazil 6,735, Netherlands 5,484, Iran 5,469, and Poland 5,464, respectively.

The fifth class included countries with less than 5,000 published documents and more than 3,000 published documents, namely: Turkey, Singapore, Indonesia, Sweden, Switzerland, Portugal, Hong Kong, Austria, Greece, Belgium, and Finland. The first four countries are in the 4,000 range, while the rest are in the 3,000 range.

The 2,000 range countries were included in the sixth class and are: Saudi Arabia, Czech Republic, Israel, Pakistan, Mexico, Denmark, Ukraine, Tunisia, Thailand, Norway, South Africa, Romania, and Egypt. Saudi Arabia and the Czech Republic published 2,966 and 2,928, respectively. Israel published 2,555 documents, while Pakistan, Mexico, Denmark, and the Ukraine published 2,498, 2,480, 2,421, and 2,407, respectively. Tunisia, Thailand, Norway, South Africa, Romania, and Egypt published, 2,371, 2,209, 2,184, 2,063, 2,049, and 2,034, respectively.

The 1,000 range was the seventh class, which included: Ireland, Morocco, Algeria, New Zealand, Bangladesh, Viet Nam, Colombia, Chile, Hungary, United Arab Emirates, and Slovakia. Ireland published 1,770 documents and Morocco published 1,630. Algeria published 1,521 and New Zealand published 1,404 documents. Bangladesh published 1,342 documents, Viet Nam published 1,279, and Colombia published 1,238 documents. Chile published 1,151, Hungary published 1,103, United Arab Emirates 1,079, and Slovakia published 1,069 documents.

Table 2: Suggested classification of countries according to the number of publications in computer science.

Class	Published Documents Count	Countries
1	60,000 – 79,507	China and USA
2	29,051 – 18,849	India, Germany, UK
3	15,731 – 10,474 a. 15,731	Japan, France, Italy, South Korea, Canada, and Spain 1. Japan, France

	– 15,048 b. 11,067 – 11,058	2. South Korea, Canada
4	5,000 to less than 9,000	Russian Federation Australia, Taiwan, Malaysia, Brazil, Netherlands, Iran, and Poland
5	3,000 to less than 5,000	Turkey, Singapore, Indonesia, Sweden, Switzerland, Portugal, Hong Kong, Austria, Greece, Belgium, Finland
6	2,999 – 2,000 a. 2,966 – 2,928 b. 2,555 c. 2,498 – 2,407 d. 2,371 – 2,034	a. Saudi Arabia and the Czech Republic. b. Israel c. Pakistan, Mexico, Denmark and Ukraine d. Tunisia, Thailand, Norway, South Africa, Romania, Egypt
7	Less than 2,000 a. 1,770 – 1,630. b. 1,521 – 1,404. c. 1,342 – 1,238 d. 1,151	a. Ireland, Morocco, Algeria, New Zealand, Bangladesh, Viet Nam, Colombia, Slovakia. Ireland, Morocco b. Algeria, New Zealand published c. Bangladesh, Viet Nam, Colombia published. d. Chile, Hungary, United Arab Emirates, and Slovakia.

	– 1,069	
8	Less than 1,000	50 countries: Serbia, Argentina, Iraq, Jordan, Croatia, Slovenia, Philippines, Cyprus, Nigeria, Luxembourg, Bulgaria, Lebanon, Macao, Kazakhstan, Sri Lanka, Estonia, Lithuania, Peru, Macedonia, Latvia, Oman, Kuwait, Iceland, Belarus, Venezuela, Bosnia and Herzegovina, Cuba, Uruguay, Azerbaijan, Malta, Ethiopia, Palestine, Kenya, Ghana, Libya, Puerto Rico, Georgia, Costa Rica, Brunei Darussalam, Armenia, Bahrain, Cameroon, Tanzania, Mauritius, Trinidad and Tobago, Botswana, Moldova, Syrian Arab Republic, Zimbabwe, Uzbekistan.

The eight classes had more than 50 countries with less than 1,000 published documents. These countries included Serbia, Argentina, Iraq, Jordan, Croatia, Slovenia, Philippines, Cyprus, Nigeria, Luxembourg, Bulgaria, Lebanon, Macao, Kazakhstan, Sri Lanka, Estonia, Lithuania, Peru, Macedonia, Latvia, Oman, and Kuwait, etc. The number of published documents a country produces in a year is a good reflection of the mental productivity of the country. Many factors affect the number of published documents a country publishes. This paper discusses six factors related to a country’s ability to produce published computer science research literature: GDP(PPP), Population, Internet Users, Number of Universities (webometrics, 2019), Education Expenditures (% of GDP), and Research and Development Expenditure (% of GDP). The correlation between two variables was conducted using the following formula:

$$\text{Correl}(X,Y) = \frac{\sum(x-\bar{\bar{x}})(y-\bar{\bar{y}})}{\sqrt{\sum(x-\bar{\bar{x}})^2 \sum(y-\bar{\bar{y}})^2}} \qquad (1)$$

Where x and y are two arrays of numbers that have some relationship between them and fall between 1 and -1. The correlation coefficient is a statistical measure that calculates the strength of the relationship between the relative movements of two variables. Pearson's correlation coefficient is used to represent the relationship between all five variables with the published documents given by the country in the SCOPUS citation database. Research and Development Expenditure (% of GDP) is the percentage countries spend on research and development from the gross domestic product (GDP) (Indicator, 2019). The data was collected from the UNESCO Institute for Statistics from the website of the World Bank (Indicator, 2019).

GDP(PPP), according to (GDP, 2019) is defined as: "GDP or Purchasing Power Parity (PPP) compares the gross domestic product (GDP) or value of all final goods and services produced within a nation in a given year. A nation's GDP at purchasing power parity (PPP) exchange rates is the sum value of all goods and services produced in the country valued at prices prevailing in the United States". Education Expenditures (% of GDP), according to (Education Expenditures, 2019)"compares the public expenditure on education as a percent of GDP". Population "compares estimates from the US Bureau of the Census based on statistics from population censuses, vital statistics registration systems, sample surveys pertaining to the recent past, and on assumptions about future trends.”

Table 3: Correlation Among the Five Factors.

	GDP (PPP)	Internet Users	Education Expenditures (% of GDP)	Population	Number of Universities	Research & Development Expenditure (% of GDP)	Published Documents 2017
GDP(PPP)	1						
Internet Users	0.92	1					
Education Expenditures (% of GDP)	-0.10	-0.10	1				
Population	0.80	0.94	-0.13	1			
Number of Universities	0.81	0.77	-0.12	0.81	1		
Research & Development Expenditure (% of GDP)	0.29	0.19	0.17	0.08	0.17	1	
Published Documents 2017	0.98	0.89	-0.07	0.76	0.75	0.38	1

Internet users, according to the Central Intelligence Agency, World Fact Book (2019) (Population, 2019), compares the number of users in a country that access the Internet. Statistics vary from country to country and may include users who access the Internet at least several times a week to those who access it only once within a period of several months (Internet users, 2019). There is a strong, positive relationship between the number of published documents in computer science and GDP(PPP). In measuring this relationship using Pearson's correlation coefficient, the measure was 0.98, see table 3. In the strength of relationship, there was found to be a positive relationship between Internet users and the number of published documents in computer science, which amounted to 0.89 using Pearson's correlation coefficient. Such an anomaly is understandable since there is a strong, positive relationship between GDP(PPP) and Internet users (0.92) using Pearson's correlation coefficient, see table 3.

There is a positive strong relation between Research and Development Expenditure (% of GDP) and the number of published documents in computer science, which amounted to (0.38) using Pearson's correlation coefficient. Yet, the relationship with the other factors was not as strong: with GDP(PPP) the Pearson's correlation coefficient was (0.29), with Internet Users, Pearson's correlation coefficient was (0.19), with Education Expenditures (% of GDP) was (0.17), with Population was 0.08, and with Number of Universities was (0.17), see table 3. There was a negative and weak relation between Education Expenditures (% of GDP) and the rest of the factors: with GDP(PPP) Pearson's correlation coefficient was (-0.10) and the same was the relationship with Internet Users. With

Population, Pearson's correlation coefficient was (-0.13), Number of Universities was (-0.12) and, finally, with Published Documents was (-0.07).

4. RESULT

In this section, the means and methods used by China and India to soar to first and third in publication ranks, respectively is discussed. The detailed examined methods and means were grouped into seven categories, as suggested by studied literature: Laws and Regulations, Education, Economy, Knowledge Transfer, Planning, Growing R&D Workforce, and Private and Public investment, see figure 2.

Both China and India's ranks soared in the years of the study towards the first and third ranks in publications as indexed by Scopus. In fact, (Chatterjee & Sahasranamam, 2018) studied more than 162 articles on technological innovation published about China and India for the period 1991–2015. Many studied the research output of India including (Banshal, Singh, Basu, & Muhuri, 2017), (Bid, 2016), (Gupta, Dhawan, & Gupta, 2015), and (Pradhan & Sahu, 2018). (Pradhan & Sahu, 2018), (Banshal, Singh, Basu, & Muhuri, 2017), (Bid, 2016), and (Gupta, Dhawan, & Gupta, 2015). And many scholars studied China's progress, such as (Veugelers, 2017). This research concluded the reasons for the rise of China and India's fall in rank were:

Laws & Regulations

Economy

Knowledge Transfer

Planning

Growing R&D Workforce

Private & Public Investment.

Figure 2: Means and methods of China and India to rise in computer science publications

Both countries (China and India) tackled the challenge of increasing their computer science research output through 7 axioms: Laws & Regulations, Education, Economy, Knowledge Transfer, Planning, Growing R&D Workforce, and Private and Public Investment. This research intended to study different factors that affect the innovations of different countries. The biggest limitations faced by the researchers was the fragmentation of the different data collected in addition to the different standardizations for the data collected and analyzed. Time limitation also appeared during the research as well as the availability of resources. Although China and India rose to a very high rank, very little research literature was found that analyzed their mean and methods.

Many factors influence the human mind’s productivity. Although financial incentive is important, it has been shown in this research that other factors, such as laws, regulations, opportunity, availability, economy, education, and knowledge transfer have an influence on the reflection of innovations that resulted in published works. Hence, based on this study’s research findings, governments can distribute effort and money based on the model suggested, and/or consult on such a model with the goal of increasing their innovation productivity.

5. CONCLUSION

This paper examined the number of computer science publications over the years, the rise and fall of some countries regarding ranking relating to computer science published documents. Thirty-nine countries rose in rank, 6 countries remained the same and held their rank, while 59 countries dropped in rank. A gap analysis was presented according to publication numbers. A classification was suggested according to computer science documents published in 2017, and seven classifications were further sub-classified, reflecting the gap in numbers of published computer science documents.

The researchers then examined the factors affecting the number of computer science documents published in 2017. This study focused on six factors: GDP(PPP), Population, Internet Users, Number of Universities, Education Expenditures (% of GDP), and Research &

Development Expenditure (% of GDP), as well as their correlation relating to the number of computer science research documents published in 2017. This paper also discussed China and India's means and methods to increase their rank, which was reflected in seven methods and means: Laws and Regulations, Education, Economy, Knowledge Transfer, Planning, Growing R&D Workforce, and Private and Public investment.

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