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Research Productivity of Nanotechnology as mirrored on SCImago Website

Chandran Velmurugan

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Librarian and Head, Department of Library, Vivekanandha Arts and Science College for Women, Veerachipalayam, Sankari, Salem Dt., Tamil Nadu 637303, India.

Address for correspondence

Chandran Velmurugan, Librarian and Head, Department of Library, Vivekanandha Arts and Science College for Women, Veerachipalayam, Sankari, Salem Dt., Tamil Nadu 637303, India.

E-mail: murugan73@gmail.com

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Abstract

This paper has made an attempt to analyze the nanotechnology research productivity which was retrieved from SCImago website during the period between 2001 and 2015. This paper tries to focus the various parameters such as country-wise distribution, year-wise output, citable documents, citations, and self-citations and many more characteristic features were analyzed during the period of study. The findings of the study revealed that the minimum output (6655), maximum output (45236), mean (24664.14), median (24337), standard error (3540.879), standard deviation (13248.76), sample variance (1.76E+08), kurtosis value (-1.42297) and skewness (0.128334) were identified using SPSS version 15. Further, the detailed findings of the study on Nanotechnology have also been illustrated.

Keywords: Scientometrics; Nano; Nanotechnology; SCImago; Bibliometrics; Trend analysis.

Introduction

Nanotechnology has been advertized as the next 'Industrial Revolution' of our modern age. Nanotechnology is a multidisciplinary concept and is a widely used technology in almost all fields such as Chemistry, Physics, Material Science, Medicine, Science and Technology, Food Technology etc. Owing to Information and Communication Technology (ICT), the drastic change and rapid growth and development have been increased in every field and Nanoscience and Nanotechnology is not an exception. The recent research in Asian Tiger Economies research papers in Asian-Pacific Economic Literature[1], stroke-related research in Taiwan in Scientometrics[2], Tuberculosis research in India and China in Current Science[3], epidemiology research in American Journal of Epidemiology[4], Research Trends in Indian Journal of Pure and Applied Physics literature output in Asian Review of Social Sciences[5], Publication Research Trends on Technical Review Journal in International Journal of Digital Library Services[6], Journal of Information Literacy[9] and Library Herald[10] were referred for the present study. In the digital divide, information has been shared through various ways by using a number of statistical methods by Librarians and Information Managers (LIM). Scientometrics is one of the quantitative tools which are often used based on bibliometrics to evaluate scholarly publications such as journal articles, conference proceedings, reviews, and so on.

Objectives

The main purpose is to know about the research

growth trends in terms of scholarly communications on nanotechnology during the period of time between 2001 and 2015 and the other objectives are as follows —

- To enumerate year-wise scholarly publications on Nanotechnology,
- To identify the country-wise research output,
- To evaluate relative growth rate (RGR) and doubling time (DT) during the study period,
- To measure the publication efficiency index (PEI) on Nanotechnology literature,
- To compute compound annual growth rate (CAGR) during the period of study,
- To correlate between citations and publications of Nanotechnology, and,
- To determine the average citation per paper (ACPP) on Nanotechnology output.

Hypotheses

1. Relative growth rate is an increasing trend and doubling time is a decreasing trend during the study period.
2. There is insignificant association between countries and publications.

Materials and Methods

To fulfill the above objectives, the required data such as year and country-wise articles, citations, citable documents and self-citations on Nanotechnology were gathered from the SCImago website during the period from 1st January 2001 to 31st December 2015. The search option carried the ''Nanotechnology'' and the search result yielded 3,52,041 records from 1,472 countries. The cited documents were 3,47,473 literature outputs and the uncited documents were 4,568 research outputs. The collected data were analyzed using MS-Excel spread sheet. Further, the data were evaluated using SPSS software version 10 such as minimum output (6655), maximum output (45236), mean (24664.14), median (24337), standard error (3540.879), standard deviation (13248.76), sample variance (1.76E+08), kurtosis value (-1.42297) and skewness (0.128334). Various scientometric tools were also used. To estimate the research output based on the data, the following scientometric tools such as Relative Growth Rate (RGR), and Doubling Time (DT), Pearson's Correlation analysis and trend analysis have been employed to test the hypotheses, so as to retrieve better results for the study.

Scientometric indicators used

Relative growth rate (RGR)

The relative growth rate (RGR) is the increase in the number of research publications/pages per unit of time. The relative growth rate and the doubling time models were developed by Garg and Padhi in 1999 to measure the publications[7]. The growth rate of total research papers published on SCImago by scientists from all over the world has been evaluated as per the following equation 1.

$$R(a) = \frac{(W_2 - W_1)}{(T_2 - T_1)} \quad ...(1)$$

Where, R (a) = Relative Growth Rate over the specific period of interval, W_1= log w_1 (Natural log of initial number of publications), W_2= log w_2 (Natural log of final number of publications), T_2- T_1 = Unit difference between the initial and final time, R (a) = per unit of publications per unit of time (Year).

Doubling Time (DT)

There exists a direct equivalence between the relative growth rate and the doubling time. If the number of research output or pages of a subject get doubled during a given time period then the difference between the logarithms of numbers at the beginning and end of this period must be the logarithm of the number 2. If natural logarithm is used, this difference has a value of 0.693. Thus, the corresponding doubling time for each specific period of interval and for both articles and pages can be calculated based on the given formula.

$$\text{Doubling Time DT} = \frac{0.693}{\text{RGR}} \quad ...(2)$$

Citations per Paper (CPP)

Citations per Paper (CPP) or Average Citations per Paper (ACPP) was used to evaluate the impact of a publication of years, countries, institutes and authors. The formula of CPP or ACPP is:

$$\text{CPP} = \frac{\text{Total No. of Citations for a Discipline or Country or Institutions}}{\text{Total No. of Papers for India}} \quad ...(3)$$

Publication Efficiency Index (PEI)

Relative research effort is being measured by the Publication Efficiency Index (PEI) and it is based on the references appended to the research articles by the authors. It indicates whether the impact

of the publications in a year in a research field is compatible with the research efforts of the world. It is described by the ratio of publication efforts to the publications. PEI is calculated by using the formula derived from the Activity Index suggested by Price[8]. The formula is expressed as given below.

$$PEI = \frac{TNC_i / TNC_t}{TNP_i / TNP_t} \quad ...(4)$$

Where,

TNC_i = total number of references in a year; TNC_t = total number of references for all the years; TNP_i = total number of papers in a year; TNP_t = total number of papers for all the years.

The value of PEI > 1 for a country indicates that the impact of publications is more than the research effort devoted to it for that particular country and vice versa. PEI has been analyzed for various block periods, for number of authors, for collaboration pattern and institutions.

Compound Annual Growth Rate (CAGR)

Compound Annual Growth Rate (CAGR) is the mean annual growth of research output over a specified period of time longer than one year. To measure the compound annual growth rate, divide the value of a research paper at the end of the period in question by its value at the beginning of that period, raise the result to the power of one divided by the period length, and subtract one from the subsequent result. The equation is given below.

$$CAGR = \left(\frac{\text{Ending Value}}{\text{Beginning Value}}\right)^{\left(\frac{1}{\#\text{ of years}}\right)} - 1 \quad ...(5)$$

Pearson's Coefficient of Correlation

Correlation is a well known statistical measure frequently used in statistical analysis of data. Pearson's Coefficient of correlation has been used to measure the relationship between different sets of data. For the present study, it deals with identifying the relationship between the number of research publications and the number of countries.

Pearson's correlation $r = = \sum xy / \sqrt{(\sum x^2 \sum y^2)}$ ...(6)

Analysis and Findings

Growth rate of publications

The growth rate of nanotechnology publications has been evaluated which were produced in SCImago website during the period from 2001 to 2015. The year-wise growth trend has been measured by using the scientometric indices such as relative growth rate (RGR) and doubling time

Table 1: Growth rate of publications

S. No.	Year	No of papers	Cum. No of papers	W_1	W_2	RGR	Mean (a) 1-2	DT 0.693/RGR	Mean pt (a) 1-2
1	2001	6743	6743	-	8.816	-		-	
2	2002	6655	13398	8.816	9.502	0.686	0.47	1.010204	
3	2003	8347	21745	9.502	9.987	0.485		1.428866	1.60
4	2004	10294	32039	9.987	10.374	0.387		1.790698	
5	2005	11988	44027	10.374	10.693	0.319		2.172414	
6	2006	14193	58220	10.693	10.972	0.279		2.483871	
7	2007	19347	77567	10.972	11.259	0.287	0.252	2.414634	
8	2008	23472	101039	11.259	11.523	0.264		2.625	2.79
9	2009	25202	126241	11.523	11.746	0.223		3.107623	
10	2010	29111	155352	11.746	11.953	0.207		3.347826	
11	2011	33793	189145	11.953	12.150	0.197		3.517766	
12	2012	36279	225424	12.150	12.326	0.176	0.16	3.9375	
13	2013	38501	263925	12.326	12.483	0.157		4.414013	4.29
14	2014	42880	306805	12.483	12.634	0.151		4.589404	
15	2015	45236	352041	12.634	12.772	0.138		5.021739	
Total		352041					0.294		2.893

(DT) model which were used for analysis (Table 1).

It is very lucid that the doubling time has been increased and the range is from 1.01 to 5.022. The mean doubling time is 1.60 during the period 2001–2005 and it has increased to 2.79 for the period between 2006 and 2010. It further increased to 4.29 during 2011–2015. The overall study period of research papers has witnessed a mean doubling time of 2.893. It was found that the doubling time of scholarly publications on Nanotechnology has shown an increasing trend. On the other hand, the relative growth rate of total literature outputs published has gradually decreased. The growth rate is 0.69 in 2002, which decreased up to 0.138 in 2015. The mean relative growth rate is 0.47 during the period 2001–2005 and it has been decreased to 0.16 during the year 2006–2015. The overall study period of research articles have been calculated and it witnessed a mean relative growth rate of 0.294. The hypothesis (one), ***"Relative growth rate is increasing trend and doubling time is in decreasing trend during the study period"*** *has not proved* and it has been rejected.

Compound Annual Growth Rate (CAGR)

To evaluate the Compound annual growth rate (CAGR) of research papers on Nanotechnology during 2001–2015. It is divided by the ending value of the portfolio to the portfolio's starting value (45236/6743 = 6.7085) and raise the result to the power of 1 divided by the number of years (1-14) and subtract one from the resulting value finally. It can be measured based on the data of Nanotechnology and evaluated;

= [(45236/6743) ^ (1/14)]

= 1.1456 -1

= 0.1456 or 14.56%

Hence, the compound annual growth rate (CAGR) for the period of 15 years of global-wise Nanotechnology literature output is equal to 14.56%.

Country and their publications (correlation)

The correlation coefficient (CC) is a measure that determines the degree to which two variables' movements are associated. The range of values for the correlation coefficient is from -1.0 to 1.0. a correlation of –1.0 represents a perfect negative correlation whereas a correlation of 1.0 represents a perfect positive correlation. Here, Nanotechnology literature has been taken and the two variables such as countries and research papers. The countries are denoted by X and number of research publications are denoted by Y during the study period from 2001 to 2015 (Table 2).

Pearson's correlation $r = \sum xy / \sqrt{(\sum x^2 \sum y^2)}$

$= 518204352 / \sqrt{(2166784 \times 1.239329)}$

$r = 1.18$

Researchers measured the correlation coefficient and it was found to be 1.18 and showed a positive correlation between the number of citations and publications. The second formulated hypothesis (two), ***"There is a significant relationship between***

Table 2: Country and their publications (correlation)

Year	Country (X)	No of papers (Y)	XY	X_2	Y_2
2001	71	6743	478753	5041	45468049
2002	75	6655	499125	5625	44289025
2003	80	8347	667760	6400	69672409
2004	83	10294	854402	6889	105966436
2005	84	11988	1006992	7056	143712144
2006	93	14193	1319949	8649	201441249
2007	96	19347	1857312	9216	374306409
2008	106	23472	2488032	11236	550934784
2009	106	25202	2671412	11236	635140804
2010	108	29111	3143988	11664	847450321
2011	109	33793	3683437	11881	1141966849
2012	112	36279	4063248	12544	1316165841
2013	116	38501	4466116	13456	1482327001
2014	120	42880	5145600	14400	1838694400
2015	113	45236	5111668	12769	2046295696
	$\sum X=1472$	$\sum Y=352041$	$\sum XY=518204352$	$\sum X^2=2166784$	$\sum Y^2=1.23933E+11$

the number of publications and countries'' has been proved and it has been accepted.

Publication Efficiency Index (PEI)

The value of PEI > 1 for a country indicates that the impact of publications is more than the research effort devoted to it for that particular country. Table 3 represents the year-wise Publication Efficiency Index (PEI). PEI has been computed for a period of 15 years from 2001 to 2015 with total 3,52,041 contributions of research articles. It shows that the PEI range was from 0.05 to 2.08 and the maximum number of papers was published in the year 2003 with 2.08 PEI value and ranked first, and followed by the PEI value 1.97 in the year 2005. The results revealed that the research papers published in the years from 2001 to 2010 have higher than the world average value of PEI and the remaining years (from 2011 to 2015) have lower than the world average of PEI value. Further, measured the average citation per paper was 993309.25.

Cited and un-cited papers on Nanotechnology in Global

Researchers have examined in terms of total cited and uncited literature output on Nanotechnology. It can be seen from the table 4 that out of 3,47,473 cited papers, the major portion of (12.70%) papers was cited in 2015 and the next productive (12.15%) of cited records was published in 2014 and the small amount of (1.90%) papers was cited in 2001. On the other hand, the maximum number of (1091) articles was uncited in 2015 and the minimum number of (30 each) papers were uncited in 2001 and 2002 respectively.

Table 3: Publication Efficiency Index (PEI)

S. No	Year	No of papers	Citations	ARPP	PEI
1	2001	6743	266668	39.55	1.7
2	2002	6655	301148	45.25	1.9
3	2003	8347	401625	48.12	2.08
4	2004	10294	434570	42.22	1.89
5	2005	11988	531845	44.36	1.97
6	2006	14193	554784	39.09	1.75
7	2007	19347	738210	38.16	1.69
8	2008	23472	788208	33.58	1.50
9	2009	25202	809318	32.11	1.42
10	2010	29111	897352	30.83	1.36
11	2011	33793	765596	22.65	1.00
12	2012	36279	659752	18.186	0.80
13	2013	38501	473723	12.30	0.54
14	2014	42880	272408	6.35	0.28
15	2015	45236	51267	1.13	0.05
Total		352041	7946474	22.57	

Table 4: Year wise cited and uncited papers

Year	Cited Papers	Percentage	Uncited Papers	Percentage
2001	6713	1.931948669	30	0.656742557
2002	6625	1.906622961	30	0.656742557
2003	8295	2.387235843	52	1.138353765
2004	10248	2.949293902	46	1.007005254
2005	11860	3.41321484	128	2.802101576
2006	14068	4.048659896	125	2.73642732
2007	19137	5.507478279	210	4.597197898
2008	23244	6.689440618	228	4.991243433
2009	24899	7.165736618	303	6.633099825
2010	28762	8.277477675	349	7.640105079
2011	33417	9.61715011	376	8.23117338
2012	35825	10.31015359	454	9.938704028
2013	38024	10.94300852	477	10.44220665
2014	42211	12.14799423	669	14.64535902
2015	44145	12.70458424	1091	23.88353765
Total	347473	100	4568	100

Table 5: Times Cited and self-citations on Nanotechnology

Year	No of publications	No of times Cited	With self-citations	Without self-citations	ACPP
2001	6743	266668	61352	205316	39.55
2002	6655	301148	74832	226316	45.25
2003	8347	401625	99581	302044	48.12
2004	10294	434570	114036	320534	42.22
2005	11988	531845	143394	388451	44.36
2006	14193	554784	152211	402573	39.09
2007	19347	738210	214023	524187	38.16
2008	23472	788208	234076	554132	33.58
2009	25202	809318	250094	559224	32.11
2010	29111	897352	280656	616696	30.83
2011	33793	765596	256306	509290	22.66
2012	36279	659752	224059	435693	18.19
2013	38501	473723	175292	298431	12.30
2014	42880	272408	104561	167847	6.35
2015	45236	51267	20805	30462	1.13
Total	352041	7946474	2405278	5541196	22.57
	Percentage (%)		30.27	69.73	100

ACPP - Average Citations Per Paper

Times Cited and self-citations on Nanotechnology

Table 5 indicates the number of scholarly papers that was published during 2001–2015, how many times cited and has got self-citations and didn't get self-citations on Nanotechnology. Out of 79, 46,474 cited papers, 30.27% of records were cited with self-citations and 69.73% of records were cited without self-citations and the average citation per paper was 22.57. During the period of study, the maximum number of (2,80,656) papers with self-citations was found in 2010 and in the same year, a huge number of 6,16,696 articles was identified without self-citations.

Conclusion

The findings of the study reveal that it was found that the doubling time of scholarly publications on Nanotechnology has shown an increasing trend whereas the relative growth rate of total literature outputs published has gradually decreased. The compound annual growth rate for the period of 15 years of global-wise Nanotechnology literature output is equal to 14.56%. The major portion of articles was cited in 2015 and the next productive (12.15%) of cited records was published in 2014 and the small amount of (1.90%) of papers was cited in 2001 and the maximum number of papers with self-citations was found in 2010. As far as the study is concerned, this is the first study taking data from the said website on Nanotechnology literature during the period.

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