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# MODELLING THE GROWTH OF LITERATURE IN THE AREA OF CRYSTALLOGRAPHY

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**Abstract:**

*The present study demonstrates the growth of Crystallography literature for the period 1989-2013. A total of 45320 records were extracted from the Web of Science Database for twenty five years which is used as main source of primary data for the present study. The growth models were applied for the literature of Crystallography. The result of the study indicates that, the Relative Growth Rate (RGR) of Crystallography publication found to be decreasing trend and Doubling Time (Dt) found to be increasing trend. The growth of literature in the field of Crystallography does not follow eithers Exponential growth and Logistic models. However, it closely follows closely the Polynomial, Power and Linear growth models. The study concluded that there has been a consistent trend towards increased growth of literature in the field of Crystallography.*

**Keywords:** Growth Models, Linear Growth Model, Exponential Growth Model, Logistic Growth Model, Relative Growth Rate, Doubling Time, Scientometrics.

## 1. INTRODUCTION:

Scientometric, is one of the metric sciences which are developed in 21$^{st}$ century in library and information science, can be applied to any discipline irrespective of their period of evaluation and quantitative studies of scientific studies. The assessment of research performance using Scientometric techniques is a valuable method for the identification and evaluation of the strength and weakness in scientific achievements. The generation of new scientific and technical Knowledge/Information has been accelerating over the past several years. In recent years increasing attention has been paid to the social dimensions of scientific community that produces sciences. But this unprecedented growth in literature has become a major concern for the scientists, scholars, and library professional as they try to keep themselves abreast with new advances in their subject and information professionals try to organize this knowledge. How the growth origin and language of literature reflect in various national devil activities in R & D in a matter of great concern to the managers of the manager of scientific activities in government industry and in academic community. This kind of growth study will be of practical value to the chemical scientist, library professionals and policy markers in effective management of the action.

The word ‘growth’ represents an increase in actual size, implying a change of state. In science and technology, growth may imply an increase in number of institutions, scientists, or publications, growth may imply an increase in number of institutions, scientists, or publications, etc. **Ravichandra Rao (1998**) says that a change in the size of literature over a specific period of time is termed as ‘growth of literature.’ One of the features of modern research in the twenty-first century has been the unprecedented and spectacular development in scientific inventions, discoveries, and the growth of knowledge. This has caused an unexpected accumulation of information **(Gupta et al., 2002).** Hence, there is a need to study this growth of knowledge and its dynamics. The present study is conducted with a purpose of to apply the various growth models and to assess the growth of literature in the field of Crystallography.

## 2. REVIEW OF LITERATURE:

Mahapatra (1994). Discussed the relative growth rate (RGR) and doubling time (Dt) for publications and citations which appeared in Indian library and information science journals during 1975 to 1985 were determined. The reducing trend of RGR and increasing rare for doubling time in both-publications and citations indicates that the growth is neither exponential nor linear. The size of the literature is calculated by applying logistic growth formula. Literature on different subjects follows the similar type of growth trend within equal economic, intellectual and environmental conditions and with the increase of number of publications, the number of citations will also increase.

Seetharam and Ravichandra Rao (1999) in their work compare trends in the growth of Food Science and Technology (FST) literature produced produced by CFTRI scientists, by food scientists in India, and by food scientists of the world, covering a period between 1989-2013. Further, the authors identify the best fitting growth models for actual and cumulative growth of data through various growth models. Different approaches are introduced by Gupta and Karisiddappa (2000) in their paper for studying the growth of scientific knowledge as reflected through publications and authors.

Karki et al. (2000) have studied the activity and growth of organic chemistry research in India during the years of 1971 – 1989 by using Chemical Abstract as source database. The study reveals that the activity index of India is quite lower. The growth trend of world and India follow the same pattern which shows that the output in three subfields such as amino acids, alkaloids and general organic chemistry is not going to saturate in near future. For the data exponential model has been found to be best fitted.

Sharma et al. (2002) Examined the growth of world literature and reflected in three data sets, namely , Physics Abstracts, Chemical Abstracts, Electrical, Electronics Abstracts from 1907-1994. They found that the power model describes best the growth of literature as reflected in the three data sets.

Neelamma G and Gavisiddappa Anandhalli (2015). The study reveals the various aspects of crystallography literature. such as year wise distribution, relative growth rate, doubling time of the literature, geographical wise, organization wise, Language wise, form wise, most prolific authors and funding agency etc. The highest number of articles was published in the year of 2011, while lowest numbers of research articles were reported in the year 1999. Further, the relative growth rate is gradually increases and on the other hand doubling time decreases. Most of the research publications are published in English language and most of the publications published in the form of research articles, China is the highest contributor to the field of Crystallography.

Hadagali and Anandhalli (2015) the study reveals that the growth of literature in neurology does not follow the linear or logistic model. However, it follows closely the exponential growth model, the study concludes that there has been a consistent trend towards increased growth of literature in the field of neurology.

## 3. OBJECTIVES OF THE STUDY:

The specific objectives of the study

1. To study the growth of Crystallography literature (RGR) and also compare the growth as reflected in the Web of Science among the World and India
2. To examine the doubling time (Dt) of the Crystallography literature
3. To analyse the fit of Crystallography literature for cumulative numbers of publications in terms of different models.

## 4. DATA AND METHODOLOGY:

The dataset was collected from the Web of Science database for the period 1989-2013. A total of 47138 records were received for twenty-five years. Web of Science is one of the most comprehensive database covering all subjects. Most of the research output on Crystallography is covered under the Science Web of Science. Hence, the same database is selected as a source for the present study. The keyword ‘Crystallography’ has been used for extracting the number of records available in the said database. The retrieved records were examined, classified, and analysed keeping the objectives in view. Further, the data is analysed using MS Excel spreadsheet and SPSS software.

### 4.1. Relative Growth Rate (RGR)

RGR is the growth rate relative to the size of population. It is also called as the exponential growth rate or continuous growth rate with reference to scientific literature publication. RGR means the increase in the number of articles per unit of time. Further the mean of RGR of articles over specific period can be calculated by using the formula.

$$R = \frac{W_2 - W_1}{T_2 - T_1}$$

Where:

R= Relative Growth Rate of Articles over specific period of time

W2= Log W2 (Natural log of final number of publications)

W1= Log W1 (Natural log of initial number of publications)

T2= Final Time in Years

T1= Final Time in Years

This formula even holds good for the calculations of RGR subject wise.

### 4.2.Double Time (Dt)

The doubling time is the given period required for quantity to double in size or value. It is related to RGR, where RGR is constant. The quantity undergoes exponential growth and has a constant doubling time or period which can be calculated directly from growth rate. This can be calculated by using the formula.

$$Dt(P) = \frac{Loge^2}{R(P)} = \frac{0.693}{R(P)}$$

Dt(P)= Average doubling time of publications

## 5. RESULTS AND DISCUSSION:

**Table – 1 Year wise distribution of Literature of Crystallography**

| | | World | | India | | Total | |
|---|---|---|---|---|---|---|---|
| SI NO | Publication Year | No of Articles | % age | Recs | % age | No of Articles | % age |
| 1 | 1989 | 101 | 0.22 | 2 | 0.11 | 103 | 0.22 |
| 2 | 1990 | 141 | 0.31 | 6 | 0.33 | 147 | 0.31 |
| 3 | 1991 | 841 | 1.86 | 15 | 0.83 | 856 | 1.82 |
| 4 | 1992 | 979 | 2.16 | 18 | 0.99 | 997 | 2.12 |
| 5 | 1993 | 1083 | 2.39 | 24 | 1.32 | 1107 | 2.35 |
| 6 | 1994 | 1238 | 2.73 | 26 | 1.43 | 1264 | 2.68 |
| 7 | 1995 | 1243 | 2.74 | 23 | 1.27 | 1266 | 2.69 |
| 8 | 1996 | 1378 | 3.04 | 29 | 1.60 | 1407 | 2.98 |
| 9 | 1997 | 1490 | 3.29 | 20 | 1.10 | 1510 | 3.20 |
| 10 | 1998 | 1654 | 3.65 | 29 | 1.60 | 1683 | 3.57 |
| 11 | 1999 | 1751 | 3.86 | 36 | 1.98 | 1787 | 3.79 |
| 12 | 2000 | 1869 | 4.12 | 45 | 2.48 | 1914 | 4.06 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 | 2001 | 1864 | 4.11 | 49 | 2.70 | 1913 | 4.06 |
| 14 | 2002 | 1975 | 4.36 | 54 | 2.97 | 2029 | 4.30 |
| 15 | 2003 | 2004 | 4.42 | 84 | 4.62 | 2088 | 4.43 |
| 16 | 2004 | 2123 | 4.68 | 87 | 4.79 | 2210 | 4.69 |
| 17 | 2005 | 2208 | 4.87 | 105 | 5.78 | 2313 | 4.91 |
| 18 | 2006 | 2294 | 5.06 | 113 | 6.22 | 2407 | 5.11 |
| 19 | 2007 | 2391 | 5.28 | 131 | 7.21 | 2522 | 5.35 |
| 20 | 2008 | 2429 | 5.36 | 131 | 7.21 | 2560 | 5.43 |
| 21 | 2009 | 2557 | 5.64 | 151 | 8.31 | 2708 | 5.74 |
| 22 | 2010 | 2752 | 6.07 | 135 | 7.43 | 2887 | 6.12 |
| 23 | 2011 | 2876 | 6.35 | 147 | 8.09 | 3023 | 6.41 |
| 24 | 2012 | 2928 | 6.46 | 178 | 9.79 | 3106 | 6.59 |
| 25 | 2013 | 3151 | 6.95 | 180 | 9.90 | 3331 | 7.07 |
| | | **45320 (96.14)** | **100** | **1818 (3.85)** | **100** | **47138 (100)** | **100** |

Table-1 depicts the year wise distribution of papers in Crystallography literature. The world output in Crystallography is 45320 (96.14%) records and that of India 1818 (3.85%) records. A total of 47138 records were extracted from the database for the study period 1989-2013. It is observed that there is a steady growth of publications for world. A fluctuating trend was observed for India during the study period.

**Table – 2 Relative Growth Rate (RGR) and Doubling Time (Dt) of (World)**

| Year | Quantum of output | Cumulative output | W1 | W2 | Rt(p) | Mean RP(p) | Dt(p) | Mean Dt(p) |
|---|---|---|---|---|---|---|---|---|
| 1989 | 101 | 101 | 0.000 | 4.615 | 0.000 | 0.449 | 0.000 | 3.610 |
| 1990 | 141 | 242 | 4.949 | 5.489 | 0.874 | | 0.793 | |
| 1991 | 841 | 2233 | 6.735 | 7.711 | 2.222 | | 0.312 | |
| 1992 | 979 | 4225 | 6.887 | 8.349 | 0.638 | | 1.087 | |
| 1993 | 1083 | 6218 | 6.987 | 8.735 | 0.386 | | 1.793 | |
| 1994 | 1238 | 8212 | 7.121 | 9.013 | 0.278 | | 2.491 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1995 | 1243 | 10207 | 7.125 | 9.231 | 0.217 | | 3.187 | |
| 1996 | 1378 | 12203 | 7.228 | 9.409 | 0.179 | | 3.880 | |
| 1997 | 1490 | 14200 | 7.307 | 9.561 | 0.152 | | 4.572 | |
| 1998 | 1654 | 16198 | 7.411 | 9.693 | 0.132 | | 5.264 | |
| 1999 | 1751 | 18197 | 7.468 | 9.809 | 0.116 | | 5.955 | |
| 2000 | 1869 | 20197 | 7.533 | 9.913 | 0.104 | | 6.646 | |
| 2001 | 1864 | 22198 | 7.530 | 10.008 | 0.094 | | 7.336 | |
| s2002 | 1975 | 24200 | 7.588 | 10.094 | 0.086 | 0.061 | 8.025 | 11.466 |
| 2003 | 2004 | 26203 | 7.603 | 10.174 | 0.080 | | 8.715 | |
| 2004 | 2123 | 28207 | 7.661 | 10.247 | 0.074 | | 9.403 | |
| 2005 | 2208 | 30212 | 7.700 | 10.316 | 0.069 | | 10.092 | |
| 2006 | 2294 | 32218 | 7.738 | 10.380 | 0.064 | | 10.780 | |
| 2007 | 2391 | 34225 | 7.779 | 10.441 | 0.060 | | 11.468 | |
| 2008 | 2429 | 36233 | 7.795 | 10.498 | 0.057 | | 12.155 | |
| 2009 | 2557 | 38242 | 7.847 | 10.552 | 0.054 | | 12.842 | |
| 2010 | 2752 | 40252 | 7.920 | 10.603 | 0.051 | | 13.528 | |
| 2011 | 2876 | 42263 | 7.964 | 10.652 | 0.049 | | 14.215 | |
| 2012 | 2928 | 44275 | 7.982 | 10.698 | 0.047 | | 14.901 | |
| 2013 | 3151 | 46288 | 8.055 | 10.743 | 0.044 | | 15.586 | |

**Figure-1 World Relative Growth Rate (RGR) and Doubling Time (Dt) of Articles**

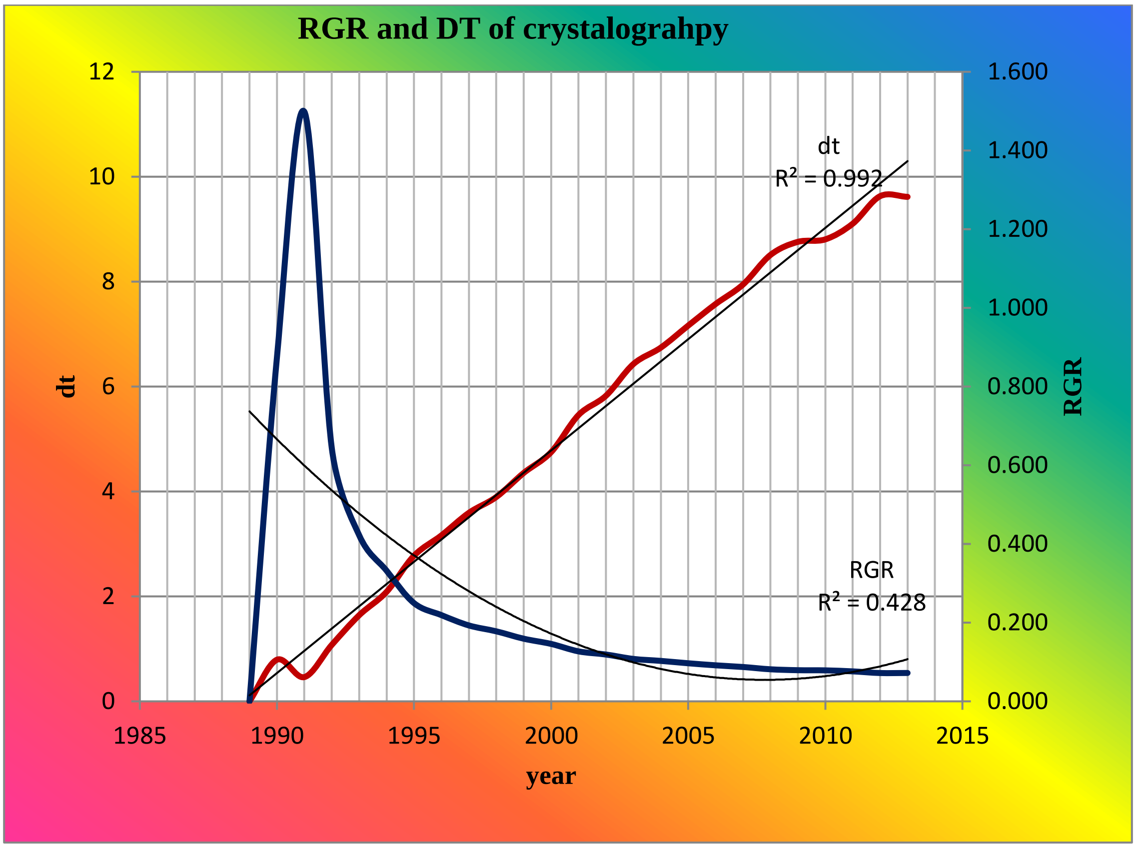



Table shows the world Crystallography contributions i.e. 45320 articles. The average relative growth rate of articles of worldwide contribution has come down from 0.874 (1990) to 0.044 (2013) over a period of twenty five years. The mean relative growth for the first thirteen years (1989 to 2001) exhibits a growth of 0.449. Similarly for the next block of twelve years (2002 to 2013) the growth is 0.061. the Relative Growth Rate found to be decreasing in trend.

At the same time, Doubling time of publication of articles increased gradually over a period from 0.793 in the year 1989 to 15.586 in the year 2013 of twenty five years. Simultaneously, the value of Doubling time (Dt) increased from0.793 in the year 1990 to 7.336 in the year 2001. In the first block period of thirteen year 3.610 (1989-2001). While in the second block period the doubling time (Dt) increased from 8.025 in the year 2002 to 11.466 in the year 2013.

Here, the mean Doubling time of the first block period is 3.601. whereas, it has increased to 11.466 (2002-2013) in the second block period. It shows that doubling time of the literature found to be increasing in trend.

**Table – 3 Relative Growth Rate (RGR) and Doubling Time (Dt) of (India)**

| Year | Quantum of output | Cumulative output | W1 | W2 | Rt(p) | Mean RP(p) | Dt(p) | Mean Dt(p) |
|---|---|---|---|---|---|---|---|---|
| 1989 | 2 | 2 | 0.693 | 0.693 | 0 | | 0.000 | |
| 1990 | 6 | 8 | 1.792 | 2.079 | 1.386 | | 0.500 | |
| 1991 | 15 | 23 | 2.708 | 3.135 | 1.056 | | 0.656 | |
| 1992 | 18 | 41 | 2.890 | 3.714 | 0.578 | | 1.199 | |
| 1993 | 24 | 65 | 3.178 | 4.174 | 0.461 | | 1.504 | |
| 1994 | 26 | 91 | 3.258 | 4.511 | 0.336 | | 2.060 | |
| 1995 | 23 | 114 | 3.135 | 4.736 | 0.225 | 0.423 | 3.075 | 2.805 |
| 1996 | 29 | 143 | 3.367 | 4.963 | 0.227 | | 3.058 | |
| 1997 | 20 | 163 | 2.996 | 5.094 | 0.131 | | 5.294 | |
| 1998 | 29 | 192 | 3.367 | 5.257 | 0.164 | | 4.232 | |
| 1999 | 36 | 228 | 3.584 | 5.429 | 0.172 | | 4.033 | |
| 2000 | 45 | 273 | 3.807 | 5.609 | 0.180 | | 3.847 | |
| 2001 | 49 | 322 | 3.892 | 5.775 | 0.165 | | 4.198 | |
| 2002 | 54 | 376 | 3.989 | 5.930 | 0.155 | | 4.470 | |
| 2003 | 84 | 460 | 4.431 | 6.131 | 0.202 | | 3.437 | |
| 2004 | 87 | 547 | 4.466 | 6.304 | 0.173 | | 4.001 | |
| 2005 | 105 | 652 | 4.654 | 6.480 | 0.176 | | 3.947 | |
| 2006 | 113 | 765 | 4.727 | 6.640 | 0.160 | | 4.336 | |
| 2007 | 131 | 896 | 4.875 | 6.798 | 0.158 | 0.144 | 4.384 | 5.024 |
| 2008 | 131 | 1027 | 4.875 | 6.934 | 0.136 | | 5.079 | |
| 2009 | 151 | 1178 | 5.017 | 7.072 | 0.137 | | 5.052 | |
| 2010 | 135 | 1313 | 4.905 | 7.180 | 0.108 | | 6.387 | |
| 2011 | 147 | 1460 | 4.990 | 7.286 | 0.106 | | 6.530 | |
| 2012 | 178 | 1638 | 5.182 | 7.401 | 0.115 | | 6.024 | |
| 2013 | 180 | 1818 | 5.193 | 7.505 | 0.104 | | 6.647 | |
| | 1818 | | | | | | | |

The Table shows the Indian Crystallography contributions i.e. 1818, the average Relate Growth Rate of articles of Indian distribution has come down from 1.386 in the year 1990 to 0.104 in the year 2013 over a period of twenty five years. The mean relative growth for the first thirteen years block period (1989 to 2001) exhibits a growth of 0.423. Similarly, for the next block of twelve years (2002 to 2013) the growth found to be 0.104.

**Doubling Time (Dt)**

At the same, Doubling time of publication of articles increased gradually from 0.500 to 6.647 over a period of twenty five years. On an average of the doubling time in the first block period (1989-2001) (Dt) is found to be 3.2.805 over a period of thirteen years. However, Doubling time (Dt) in the second block period (2002-2013) found to be 5.024 over a period of twelve years.

## APPLICATION OF GROWTH MODELS

The present study is conducted with a purpose of to apply the various growth models and to assess the growth of literature in the field of Crystallography, which is generally used in the literature for analysing Some of the models have been chosen for the study are:

**Linear Growth Model:** The linear growth Model can approximate the growth in shorter periods. It is reported that in first rate literature, exponential growth breaks down completed and there is merely a constant in each time period. In this case the growth function is linear that is the number of first rate publications at time "t" is given by; $\mathbf{Y= a+b^x}$ **.**

**Exponential Growth Model:** Exponential Growth Model is one that exist when the rate of growth is proportionally to the existing amount Exponential Growth means a rapid increase of the publications in fixed proportion for each unit of time. It is expressed in terms of percentage or doubling time. Mathematically it is represented as; $\mathbf{Y=K+ ab^x}$**.**

**Logistic Growth Model:** A logistic model is a common sigmoid function, a generalized logistic curve model the S-shaped. The initial stage of growth is approximately exponential; then, as saturation begins, the growth slows, and at maturity, growth stops. This model has been developed by Pierre Verhulst, (1838) a belgian mathematician. Logistic growth assumes that the growth rate is proportional to the product of present size and future size. This cumulative curve takes a S shaped pattern. When compared with exponential growth here an upper limit to the growth curve exists. It follows a slow inception followed by step growth and then a long period of saturation. Mathematically it is represented as; $\mathbf{1/Y=K+ab^x}$.

**Power Model:**

A power model is a functional relationship between two quantities. In the words of Rao (Rao, 2010) it is the double log model and mathematically it is represented as: $\mathbf{Y=\alpha+t^\beta}$

i.e log y=logα + β logt. It is also represented as; $\mathbf{y_t=\alpha\beta t^\Upsilon}$

where α, β > 0.

For 0< ϒ< the function y takes a concave shape.

For ϒ=1 the function y takes a linear shape.

For ϒ>1 the function y takes a convex shape.

**Polynomial Model**: A polynomial is a mathematical expression consisting of a sum of terms, each term including a variable or variables raised to a power and multiplied by a coefficient. Polynomial curve fitting common for data analysis in the field of science, engineering and social science. The standard method to fit a curve to data is to use the least squares method. In this method the coefficients of the estimated polynomial are determined by minimizing the squares of errors between the data points and fitted curve. This method is used to determine relationship between an independent and dependent variable. Historically polynomial models are among the most frequently used empirical models for curve fitting. The advantages of models are; they have a simple from, well known – understood properties, and moderate flexibility of shapes. They are easy to use. Mathematically it is represented as; $Y=ax^2+bx+c$.

**Application of Fit Statistics derived from application of various models to World and Indian Cumulative Growth of Publications in the disciplines of Crystallography**

| SI NO | Best Resulted Obtained in World Literature | | Best Results Obtained in Indian Literature | |
|---|---|---|---|---|
| | Name of the Model | $R^2$ | Name of the Model | $R^2$ |

| | | | | |
|---|---|---|---|---|
| 1 | Polynomial | 0.9903 | Polynomial | 0.9875 |
| 2 | Linear | 0.9585 | Linear | 0.9268 |
| 3 | Power | 0.8852 | Power | 0.9435 |
| 4 | Exponential | 0.6251 | Exponential | 0.8817 |

Table 8 explains the application of selected growth models to the Cumulative Growth of publications in the Crystallography for the period 1989-2013. This indicate that more than one model could explain their growth. The models evaluated in terms of their model parameters fit. The models evaluated in terms of their model parameters fit statistics and the graphical fit to the data. The best fits were shown by Polynomial model for the publication in Crystallography. This is true in the case of both Worldwide and Indian growth. Whereas, Polynomial model holds well both in the world wide and Indian growth. A part from this, the power and Linear model in the case of both literature.

## APPLCATION OF GROWTH MODELS TO WORLD CRYSTALLOGRAPHY LITERATURE

**Figure-3 Polynomial Growth Model to World Crystallography Literature**

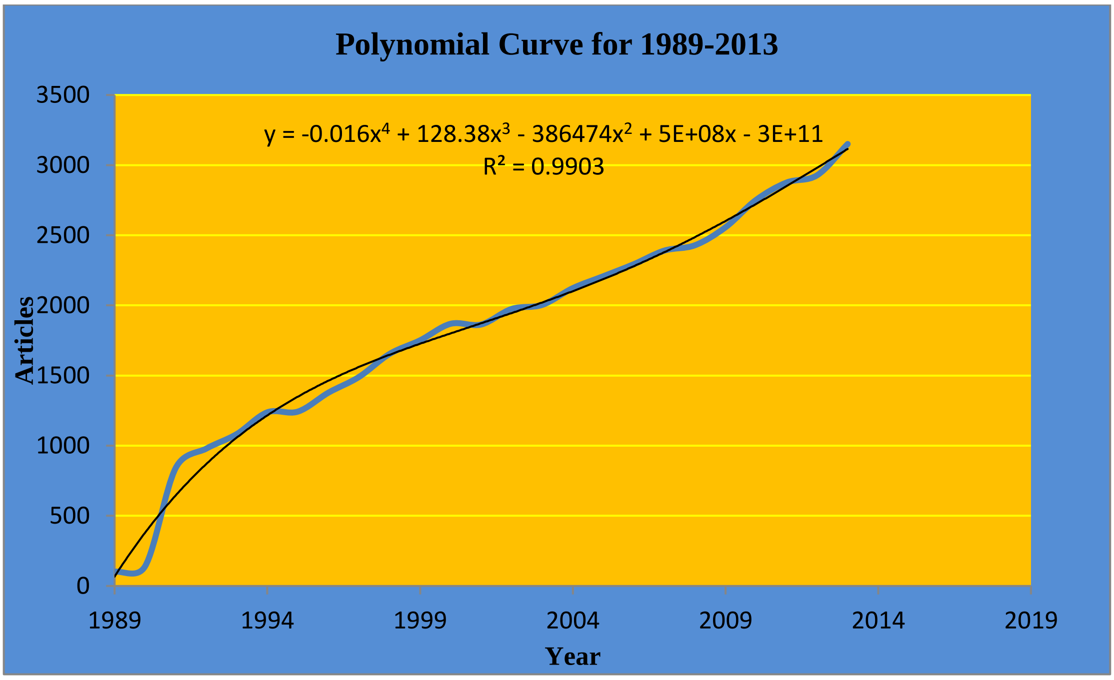


**Figure-4 Linear Growth Model to World Crystallography Literature**

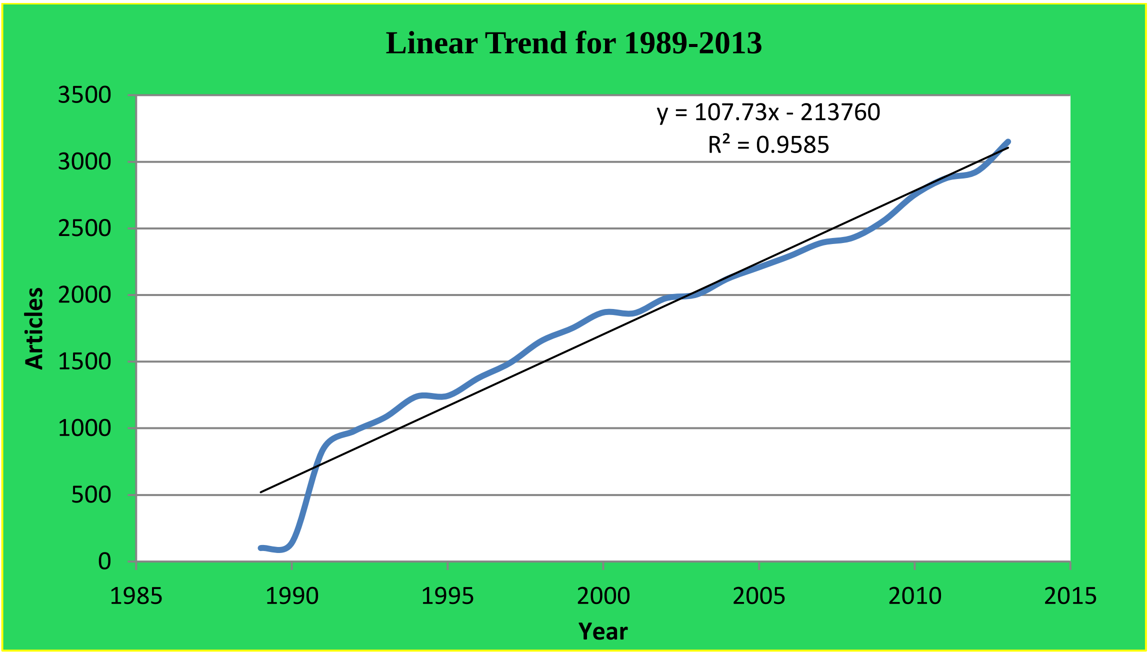



**Figure-5 Power Growth Model to World Crystallography Literature**

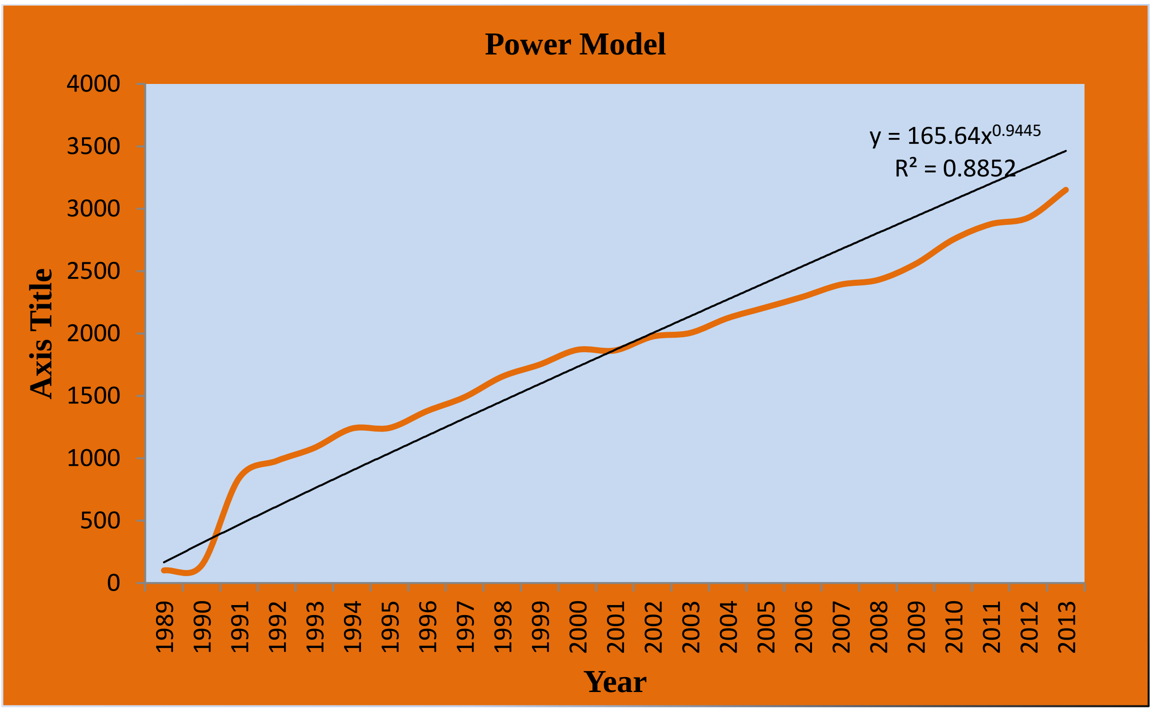
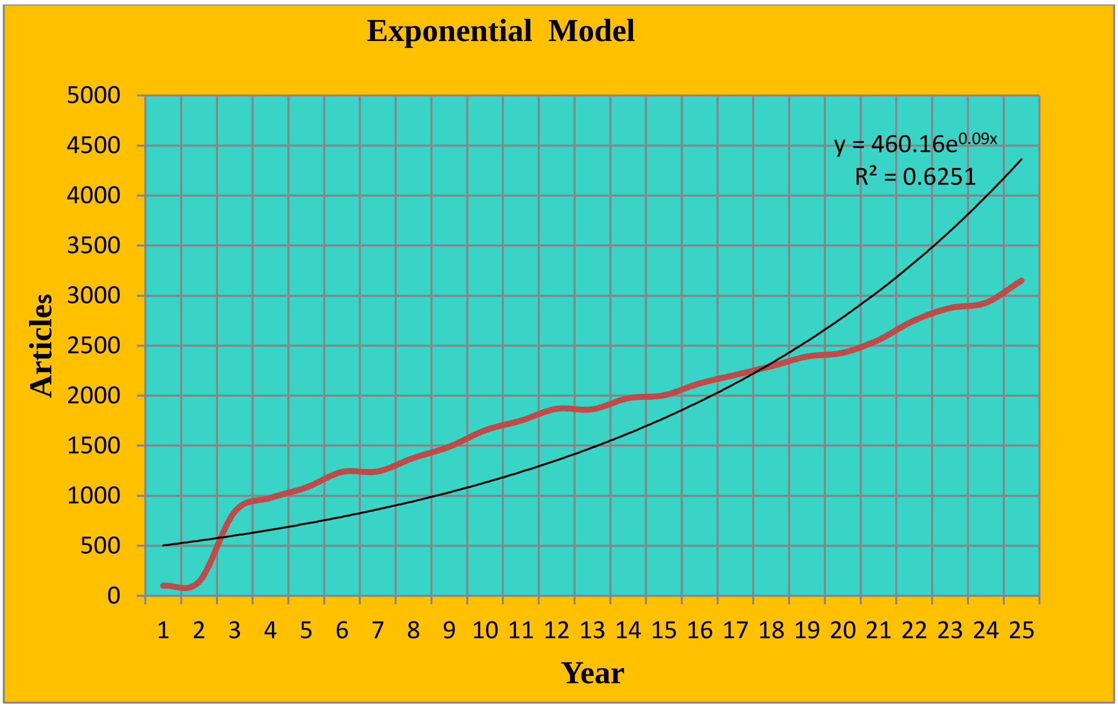



**Figure-8 Exponential Growth Model to World Crystallography Literature**




The figure 5, 6 ,7, 8 shows the World literature growth for the period 1989-2012. Figure 5 shows Polynomial model $R^2$=0.9903, Linear model $R^2$=0.9558, Power model $R^2$=0.8852 and Exponential model $R^2$=0.6251 in world Crystallography literature growth.

## APPLCATION OF GROWTH MODELS TO INDIAN CRYSTALLOGRAPHY LITERATURE

**Figure-5 Polynomial Growth Model to Indian Crystallography Literature**

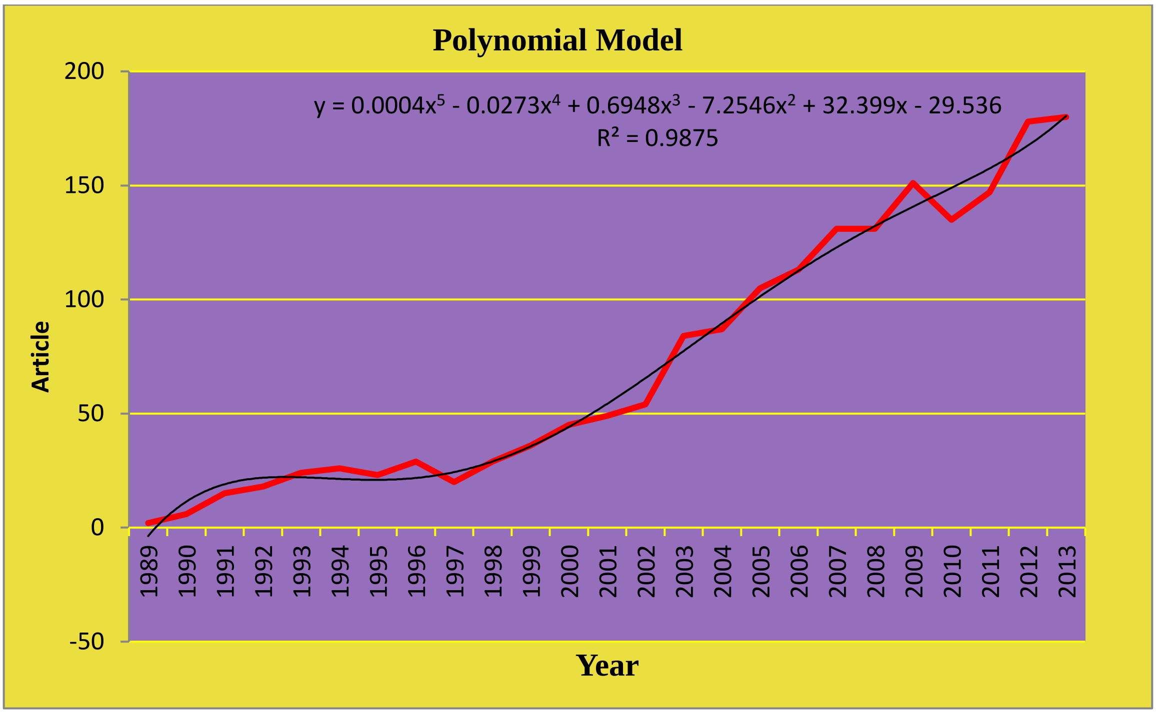



**Figure-6 Power Growth Model to Indian Crystallography Literature**

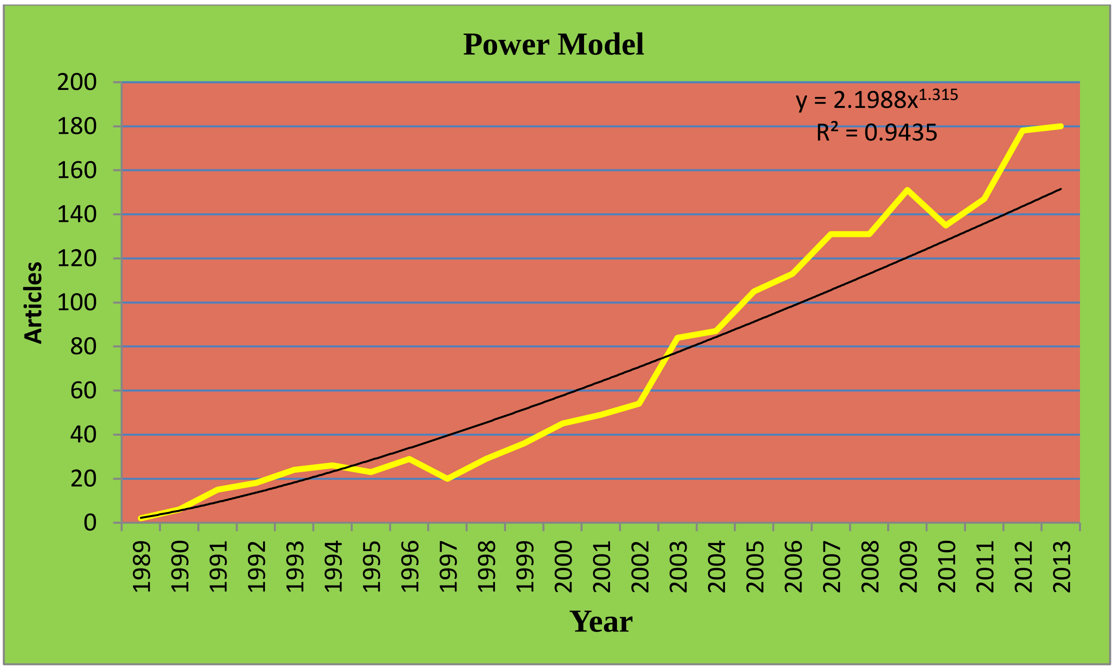


**Figure-8 Linear Growth Model to Indian Crystallography Literature**

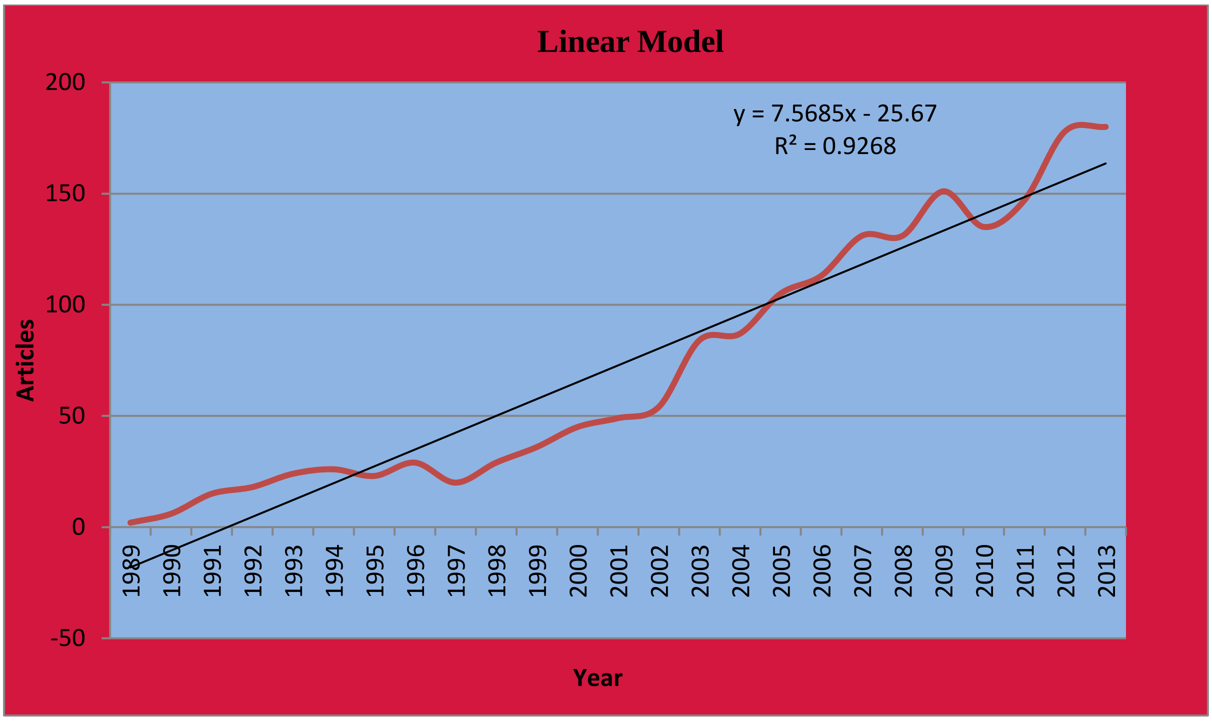
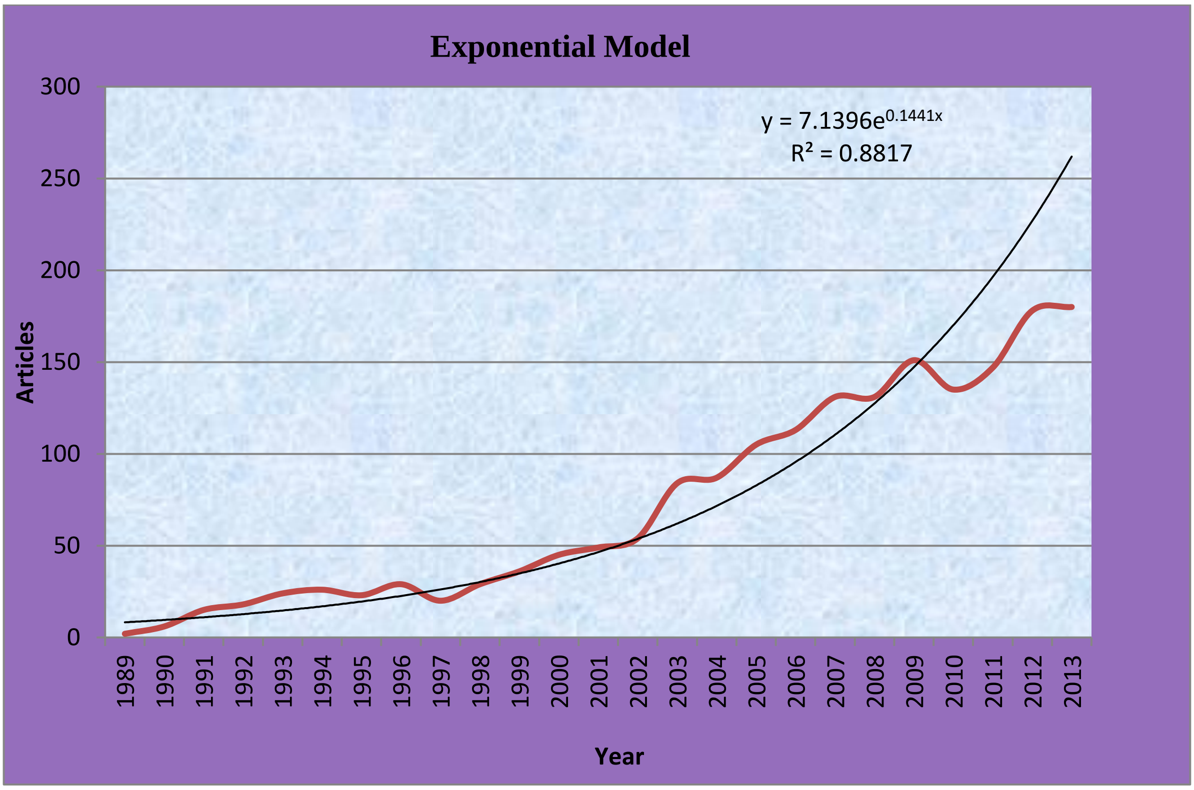



**Figure-9 Exponential Growth Model to Indian Crystallography Literature**



The figure 9, 10, 11, 12 shows the growth of World literature growth for the period 1989-2012. Figure 5 shows Polynomial model $R^2$= 0.9875, Linear model $R^2$=0.9268, Power model $R^2$=0.9435, and Exponential model $R^2$=0.8817 in world Crystallography literature growth.

**CONCLUSION:**

The study is based on 45320 research papers published between 1989-2013 as reflected in Web of Science, which is one of the most comprehensive online databases covering all the subjects. The data were collected, tabulated, and analysed. The study reveals some factual factorial data through bibliometric analysis. Research articles have been analysed for finding the year wise trend, Relative Growth Rate, Doubling time, and examining the different types of growth rate models. The maximum world contribution is observed during 2013 (3151 publications) and The outcome of the present study shows that there is a steady growth of publication in the field of Crystallography.

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