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LITERATURE GROWTH AND AUTHOR PRODUCTIVITY PATTERNS IN INDIAN PHYSICS

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Abstract—Studies the growth of Indian and World physics literature from 1900–50. Explores the applicability of selected technology diffusion models to the growth of literature in Indian and World physics. Focuses on the applicability and validity of two forms of Lotka's Law and negative binomial distribution model to the cumulative author productivity data on Indian physics. Looks at the linkages between inequality/concentration measures and development of Indian physics as a discipline. Explores the relevance and applicability of two well known generalisations, Price Square Root Law and 80/20 Rule to the cumulative author productivity data on Indian physics. Studies the increase in the number of practitioners, at different productivity levels, and the emergence of core authors in Indian physics.

1. INTRODUCTION

One of the features of world science in the recent years has been a tremendous increase in the volume and scope of scientific research leading to a voluminous growth in scientific literature. This growth has made it extremely difficult on one hand for scientists to keep track of relevant literature in their specialities and for library professionals to meet the information needs of scientists and on the other hand, for policy-makers to decide on priorities in resource allocations in different fields and specialities. A bibliometric analysis of the publications on Indian physics speciality is analysed to yield useful results and insights regarding growth pattern of literature and scientific productivity of authors.

2. AIMS AND OBJECTIVES

The main aims and objectives of this paper are as follows:

(i) To study the growth of literature and examine the applicability of selected technology diffusion models for their goodness-of-fit to the growth of research literature in Indian and World physics from 1900 to 1950.
(ii) To analyse the applicability and validity of two forms of Lotka's law and negative binomial distribution model to the cumulative author productivity data on Indian physics.
(iii) To explore the relevance and applicability of two well-known generalisations, viz. Price Square Root Law and 80/20 Rule to the cumulative author productivity data on Indian physics in different durations.
(iv) To study the increase in the number of researchers at different productivity levels and emergence of core authors in Indian physics.

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3. THE DATABASE

In this study an exhaustive bibliography, compiled by an historian, on Indian physics research papers from 1800–1950 has been analysed (Sen & Chatterjee, 1992–1993). The data on world output in physics analysed are obtained from *Physics Abstracts* (1900–1950). Since systematic bibliography or database covering research output on Indian physics from 1950 onwards is neither available in print nor in computerised format, the authors could not study research output of Indian physics beyond 1950.

The bibliography of Indian physics considered as the main source is perhaps the first major effort in the country towards the bibliographical control of physics research output in a scientific field during the pre-independence period. The study, therefore, provides an opportunity to analyse chronologically the developments in Indian physics through the analysis of research papers covered in this bibliography.

The bibliography lists 6287 research papers. An analysis of the bibliography indicates that during the period 1800–1900, a total of 338 research papers were published. Thus, on an average, there were only 67.6 papers per decade. Most of the papers published during this period flowed from the government surveys and scientific establishments, and the European workers were the prominent contributors.

The scenario of research output in the twentieth century presents a striking contrast to that in the nineteenth century. A decade-wise break up of research output from 1900 to 1950 is given below:

Period	No. of Papers Published
1900–09	75
1910–19	202
1920–29	842
1930–39	2440
1940–49	2070

The period 1909–1919 witnessed the organisation of post-graduate studies and research in the Indian universities. A few private institutions such as the Indian Association for the Cultivation of Science, the Indian Institute of Science, and the Bose Institute also originated during this period. The participants in the research efforts during this period were predominantly Indians.

The period 1910–29 saw the diversification of research in many new sub-fields, and the emergence of some brilliant physicists like C. V. Raman, M. N. Saha, etc. These physicists were instrumental in the institutionalisation of Indian physics research efforts, and also in creating a team of dedicated research workers. During this period, more than 1000 research papers were published from Indian physicists. The peak reached in Indian physics research output during 1930–39 appears to be attributable in no small measure to the quality work done by several leading physicists of the preceding decades, which attracted international recognition, including a Noble Prize in physics. A slight fall in the decade 1940–49 was probably due to the difficult war-time conditions during this period.

Based on the above analysis, we have broadly classified the total research efforts in Indian physics in following three phases/stages:

Stage 1: Period from 1800–1910, when isolated and sporadic research efforts were made in different parts of the country.

Stage 2: Period from 1911–30, which witnessed institutionalisation of Indian physics, and entry of a few brilliant physicists who in turn created a dedicated team of scientists. Foundations of research were also laid for various branches of physics during this period.

Stage 3: Period from 1931–50, saw the diversification, strengthening and consolidation of research efforts in various branches of Indian physics.

4. METHOD OF ANALYSIS

4.1. *Author productivity*

Considerable interest exists in the field on the analyses of author productivity patterns in a scientific field. Lotka was the first to observe and analyse the productivity patterns of authors in a sample data from chemistry and physics. He came out with a general formula known as Lotka's Law. Besides Lotka's Law, many scholars in the past have also fitted observed author productivity distributions to a variety of discrete theoretical probability statistical distributions such as negative binomial and geometric.

Lotka's law can be applied both as a inverse square law, as well as in its generalised form to the author productivity data. Lotka's law is usually defined in its generalised form as:

$$g(x)=k.x-{}^{\alpha};\ x=1,2,3,\ldots x_{\max};$$
$$k>0$$
$$\alpha>1$$

where $g(x)$ represents the probability of author publishing x times in a subject area; x_{max} represents the maximum size or value of productivity variable x; and k and α are the parameters to be estimated. The model was proposed originally by Lotka (Lotka, 1900) as an inverse square law in which $\alpha=2$ and $k=0.6079$. This inverse square formula is now viewed as a special case of the generalised Lotka' model defined earlier (Bookstein, 1976).

For each data set, average value of α was determined by using least squares regression method using SPSS statistical package. The value of k, the theoretical number of authors with a single article, was determined from the following formula:

$$C=\frac{1}{\sum_{x=1}^{P=1} x/\alpha+1/(\alpha-1)(P^{\alpha}-1)+1/2P^{\alpha}+\alpha/24(p-1)^{\alpha+1}}$$

where P is the number of pairs of data considered and α is the experimentally computed exponent of the distribution (Pao, 1985).

The Negative Binomial distribution model can be written as:

$$P(r)=\frac{\Gamma(h+r+1)}{T_h T_r}\ \frac{(h)^h}{w+h}\ \frac{(w)^{r-1}}{w+h}$$

where $\tau=1, 2, 3,\ldots w,\ h<0$

Mean $=w+1=x$

Variance $=w(1+w/h)=S^2$

Therefore, $w=x-1$

and
$$h=\frac{(x-1)^2}{S^2-(x-1)}=\frac{w^2}{S^2-w}$$

Here, Γ is the gamma function, w and h can be computed from the mean and variance of the data (Ravichandra Rao, 1980).

Though there are several statistical tests used in the literature to test the applicability of Lotka's law and negative binomial model, Chi-Square and Kolmogorov − Smirnove ($K-S$) tests are more popularly used. We have used here $K-S$ statistical test, which is based on the maximum absolute deviation ($D_{\max}$) between the observed and the theoretical distribution functions (Coile, 1977).

5. ANALYSIS AND RESULTS

5.1. *Application of technology diffusion model*

According to Solla Price, growth of knowledge in scientific specialities takes the form of logistic curve (De Solla Price, 1963). The growth of scientific knowledge is a kind of diffusion process in which ideas are transmitted from person to person, similar to the diffusion of innovations which have also been shown to follow the logistic growth curve (Rogers, 1962). When members of a social system are in communication with one another, a kind of 'contagion' effect occurs in which those individuals in a social system who have adopted an innovation, influence those who have not yet adopted it. The probability that a member of such a social system will adopt an innovation increases over time because it is related to the number of people who have adopted the innovation (Coleman *et al.*, 1966). Thus, on the same analogy, the growth of knowledge can be interpreted as a 'contagion process' in which early adopters (authors) influence the latter adopters (authors).

In fact, several diffusion models have been developed to represent the level or spread of innovations amongst a set of prospective adopters in a social system in terms of simple mathematical function of time that has elapsed from the introduction of innovation. By doing so, a diffusion model permits the prediction of the continued development of the diffusion process over time as well as facilitates a theoretical explanation of the dynamics of diffusion process in terms of general characteristics. To study the growth of Indian and World physics research output, we have applied a diffusion model which is a modified version of the model suggested by Sharma *et al.* (1993). This model is similar to the Mansfield model if we retain the leading term in the polynomial. The model is expressed in a differential equation form as:

$$N(t+1)=N(t)e^{b-cN(t)}\ldots \qquad (1)$$

where N represents the total number of adopters at a particular time step; and b and c are real parameters.

The coefficient b is always positive for growth while the parameter c could be negative if the saturation is not indicated by the data in near future. The number of adopters at a time step $(t+1)$ is completely determined by its number at time step t.

Since at any given point of time t,

$N(t)=n\ (t)$, the number of papers during the period t and $t-1$

$N(t)=n\ (t),\ n(t-1),\ n(t-2),\ldots\ldots,n(1)$

In the model equation, equal weight of influence has been given to those who have entered the field recently $n(t)$ and those who have entered in the field in earlier years $n(t-1)$, $n(t-2)\ldots\ldots n\ (1)$.

In actual practice, this may not hold good for all. It means that effectiveness of entrants may vary. The influence of those who have entered the field in the recent past may dominate. Thus, from among those who have entered the field up to time t, the more effective and influencing agents are those, who have entered the field in the recent past. Sharma & Bhargava (1994) have recently developed a prescription through which model can be improved. They suggest that $N(t)$ may be replaced by NS.

In earlier model the value of $N(t)$ was considered as follows:

$$N(t)=\sum_{i=0}^{i=t-1} n(t-1)$$

$$=[n(t)+n(t-1)+\ldots+n(1)]$$

Rewriting model Equation (1), we get,

$$N(t+1)-N(t)=N(t)e^{b-cN(t)}-N(t) \qquad (2)$$

$$dN/dt=N(t)e^{b-cN(t)}-N(t)$$

If $N(t)$ is assumed to be equal to NS, then the above equation can be rewritten as:

$$dN/dt=NSe^{b-cN(t)}-NS \qquad (3)$$

where $$NS=\sum_{i=0}^{i=t-1} n(t-1)w^{1} \text{ where } 0<w<1$$

Here w is a weight factor to be calculated by trial and error method. Sharma *et al.* tried different values of w, but finally they found that when $w=1/4$, the results were found to be most encouraging. If we assume $w=1/4$, we can say that effectiveness of influencing agents (i.e. of individual research paper) decreases by 25% each year. Using this approach, we have found that the model becomes quite effective in capturing not only the growth of publications but also the yearly fluctuations in the data.

We have applied this improved technology diffusion model to the growth of Indian and world physics research output from 1900–1950, on the same pattern as undertaken by Gupta *et al.* (1995). The results and parameter values obtained are presented below:

Value of parameter	Indian Data	World Data
b	0.356±0.038	0.468±0.025
c	−0.040±0.007	−0.047±0.014

The values of R^2 and F which indicate the goodness-of-fit of the models obtained are given below:

Parameters	Indian Data	World Data
R^2	0.9718	0.9960
F	576.318	4220.63

In the parameter values obtained, the value of parameter c is found to be negative both for the World and Indian physics research outputs. This shows that there is no immediate sign of saturation visual in the growth of research papers in Indian and World physics. Figures 1and 2 present the observed data and the estimates obtained from the application of the improved mathematical model to the Indian and World physics outputs from 1901–1950.

5.2. *Author productivity*

To evaluate the author productivity in a scientific field the three methods generally used are: straight counts, normal counts, and adjusted or fractional counts. 'Straight counts' assign all credits to the senior (= first) author only; 'Normal counts' give every author one credit; and 'Fractional counts' assign a credit equal to $1/n$ to each of the n co-authors. In the present study, we have used the 'Normal counts' method for measuring the author productivity. In this section

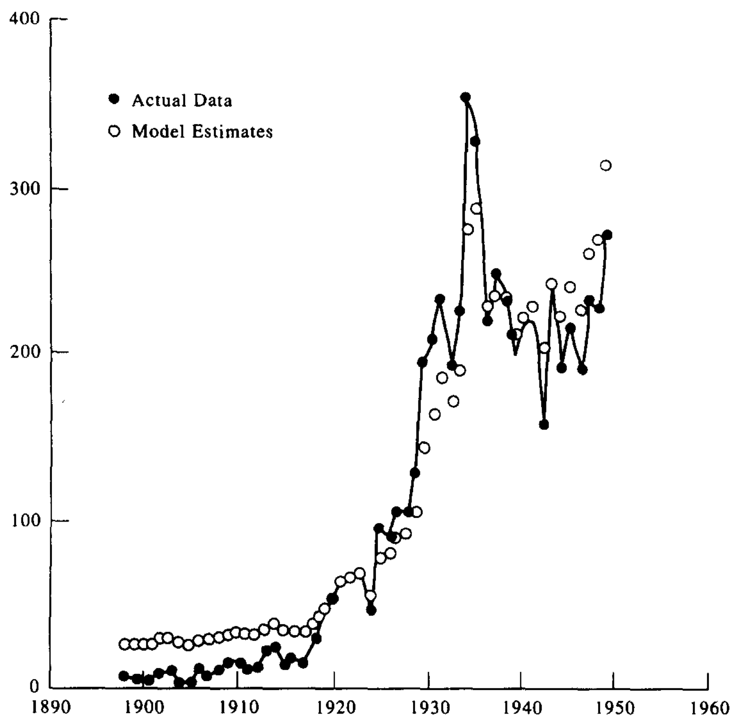

Fig. 1. The actual data and fitting of proposed model to the data on growth and Indian physics.

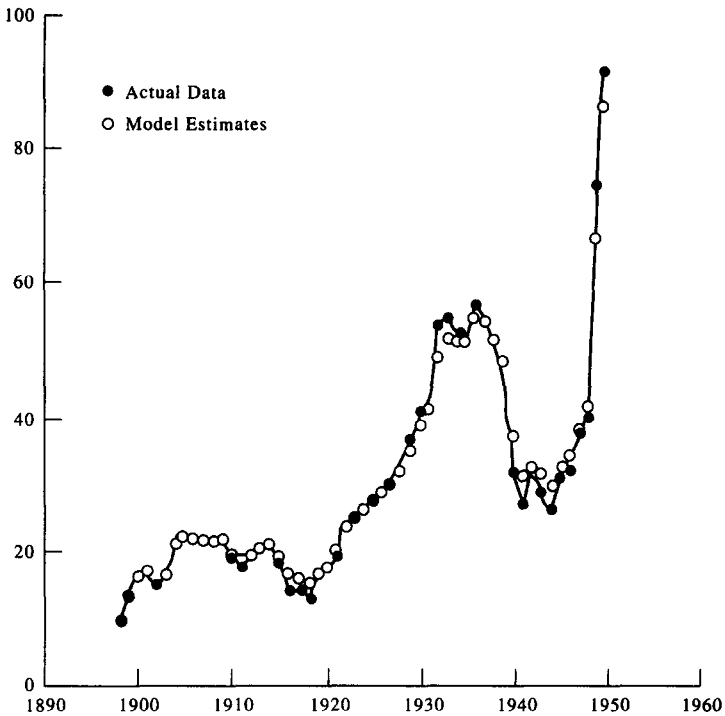

Fig. 2. The actual data and fitting of proposed model to the data on growth of world physics.

the applicability of the two forms of Lotka's law and negative binomial distribution has been studied in the cumulation author productivity data of Indian physics, for the period 1800–1950. The data have initially been divided into six files each of 10 years period and then it has been cumulated (six files).

The details about the applicability of the two forms of Lotka's law and negative binomial distribution model to the cumulated author productivity data (six files) and the overall results are presented in Table 1. We observe from Table 1 that there is no uniform trend in the applicability of three models to the cumulative author productivity data. For example, when applicability of Lotka's inverse square law was considered, we found that it is applicable to the data in first three files, from 1800–1900 to 1800–1920. Contrary results were obtained when applicability of the Lotka's general inverse power law was studied. Here, we did not find the applicability of the Lotka's law in any of the six files. In case of negative distribution model, we could see fit to the

Table 1. Value of D_{max} obtained by application of two forms of Lotka's law and negative binomial distribution

Period	Value of D_{max}						
	Lotka inverse				Negative binomial distribution		K–S Stat.
	Square law		Power law		α	D_{max}	
	α	D_{max}	α	D_{max}			
1800–1900	2	0.0676	NB	0.0766	1.20	0.5656	0.1520
1800–1910	2	0.0505	NB	0.0462	1.25	0.5544	0.1377
1800–1920	2	0.0788	NB	0.1516	1.35	0.3435	0.1135
1800–1930	2	0.0919	NB	0.1252	1.25	0.4059	0.0728
1800–1940	2	0.1022	NB	0.2507	1.40	0.2465	0.0428
1800–1945	2	0.1375	NB	0.1427	1.45	0.2774	0.0388

data in first two files pertaining to the period 1800–1900 and 1800–1910.

In order to understand and interpret these results in a speciality context, we have to first understand briefly the stages in the development of a speciality, and the expected productivity of authors/practitioners in different stages of its development.

The development of a research speciality passes through various stages. Crane (1972) identified four stages in the development of a research speciality. Stage 1 is considered as initial development of research area/speciality with many transient authors, and few authors with more than short activity. Stage 2 is known as pioneering stage, illustrating the exploding learning processes of a few pioneering contributors. There are a large number of transient authors and a few pioneering contributors in this stage, whose productivity increases systematically. The Stage 3 symbolises the situation, where the increasing productivity curve of the pioneers starts reducing. At the same time, the activity of the followers of the pioneers starts increasing in a significant manner and new authors starts appearing. The last Stage 4, in which normally the perceived interest in the field falls sharply and consequently opportunities decline, and researchers/authors start migrating to other fields.

In the initial stages of the development of a research speciality (Stage 1 and 2), one may witness a large number of transient authors, some low productive authors and few medium productive authors. We may also expect or visualise an author productivity distribution at this stage, which does not find applicability in Lotka's law or negative binomial distribution. As the speciality develops and matures, one may witness large number of authors being active and emerging at different productivity levels in the speciality. Ideally, we should expect now an author productivity distribution which should be closer to Lotka's or negative binomial distribution.

Keeping in view this hypothesis, we have studied the cumulative author productivity distribution in the development of Indian physics. The results obtained, as presented in Table 1, indicate that Lotka and negative binomial distribution are found to be applicable in some cases only at the initial stages of the development of Indian physics. This is contrary to our expectations and hypothesis. Ideally the Lotka's and negative binomial distribution should have found a better applicability at the later stages of the development of Indian physics than at its earlier stages. This observation led us to conclude that the fitting of a particular statistical distribution in author productivity data of a research speciality has no relation with its development cycle. These results are in conformity with another study recently conducted by Gupta and Karisiddappa in the area of theoretical population genetics (Gupta & Karisiddappa, 1996).

6. INEQUALITY/CONCENTRATION MEASURES

The inequality and concentration measures can be used as yardsticks for measuring the intensity of research activity in a scientific speciality. This phenomenon can best be studied using the following indicators (Gupta & Karisiddappa, 1996):

(a) Average number of publications per author
(b) The α measure, calculated through regression.
(c) The Gini coefficient varying from 0 to 1, used as a measure of concentration. The Gini coefficient is calculated by the following formula:

$$g=\frac{2[n+1/2-q]}{n} \quad \text{with } q=ia_i/t$$

where n is the number of classes; a_i the size of the class of rank i of the classes ranked by size; and t is the sum of the class size.

The α measure is normally used in the literature as a measure of inequality in the distribution of author productivity. The increase in the value of α is normally associated with an increase in

Table 2. Indices of concentration and inequality obtained from cumulated productivity of authors data of Indian physics

Period	No. of authors	No. of papers	Mean	Variance	Gini index	α
1800–1900	115	323	2.80	16.82	0.3757	−1.20
1800–1910	140	407	2.90	17.70	0.3932	−1.24
1800–1920	206	698	3.38	46.00	0.4663	−1.23
1800–1930	500	1963	3.92	81.94	0.5164	−1.24
1800–1940	1218	5241	4.30	78.15	0.5478	−1.39
1800–1950	1758	8028	4.56	86.78	0.5548	−1.45

the proportion of less productive authors.

Table 2 provides the data on the average number of papers per author, the value of exponent α, and value of Gini coefficient of the cumulative author productivity data of Indian physics. It has been found that as the Indian physics speciality grows and develops from Stage 1 to Stage 2 and then to Stage 3, it witnesses on one hand a continuous entry of new authors, and on the other hand, the productivity of a few important and significant authors markedly increases with time. This leads to an increase in concentration in productivity of authors, which is reflected in the increasing value of Gini coefficient over time (Table 2). With the increase in concentration, we also observe that the inequality between more productive and less productive authors increases, which is reflected in the decreasing value of α with time.

7. APPLICABILITY OF PRICE SQUARE LAW AND 80/20 RULE

There are two significant generalisations on author productivity: Price Square Root Law (De Solla Price, 1963) and 80/20 Rule (Kyvik, 1989; Pao, 1986). According to Price Square Root Law, fifty per cent of the published research output in a subject field should be contributed by square root of the total number of authors at a given point of time. According to second generalisation, 80 per cent of the total research outputs in a subject field should be contributed by 20 per cent of the elite or most productive scientists at a given point of time. It will be useful here to look at the relevance of these two generalisations in cumulative author productivity data of Indian physics.

The data on the extent of contribution made by square root, 10%, 20% and 30% of the total authors in Indian physics when studied indicate that the contribution of the square root of authors varies across different time periods, the maximum and minimum being 44.25% (1800–1890) and 13.08% (1900–1950), and the average being 37.59%. No uniform trend in the percentage of contribution, either on the increasing or decreasing side, with respect to time is observed in the data. As a result, one can say that there is no relationship in author productivity data between Price Square Root Law and the development of the Indian physics as a speciality.

In contrast, one finds a positive correlation in the author productivity data in the case of 80/20 Rule. Twenty per cent of the authors have contributed papers ranging from around 60% (1800–1890) to around 70% (1800–1950), the average being 65.2%. We also observe an increasing trend in the percentage of contribution by 20% of authors over the years. Although average percentage of contribution by 20% authors is 65.2%, which is below 80% as predicted by 80/20 Rule, but we hope that this percentage will increase as Indian physics further develops, grows, and matures.

8. GROWTH OF PRACTITIONERS IN INDIAN PHYSICS

For the sake of convenience, we have divided the total practitioners into four groups based on their output: Group 1, consisting of practitioners/authors contributing one or two papers

Table 3. Cumulated growth of authors/practitioners at different productivity levels in Indian physics

Period	Number of authors in productivity range (with papers)				Total authors
	1–2	8–10	11–25	26–	
1800–1880	71	22	2	1	96
1800–1890	80	22	3	1	106
1800–1900	85	23	6	1	115
1800–1910	102	30	7	1	140
1800–1920	146	48	8	4	206
1800–1930	338	127	26	9	500
1800–1940	813	303	68	34	1218
1800–1950	1114	484	208	52	1758

(floating or inactive population); Group 2, consisting of practitioners/authors contributing three to ten papers (low productive group); Group 3, consisting of practitioners/authors contributing between eleven to twenty five papers (medium productive); and Group 4, consisting of practitioners/authors contributing above 25 papers (highly productive). The last two groups are important because they are considered as the major contributors of ideas in the field.

The data in Table 3 present the cumulative growth of practitioners/authors in the field and changes in their level of productivity in different periods, in the development of the Indian physics. In terms of absolute numbers, the number of practitioners has increased from a maximum of 140 (Stage 1) to a maximum of 500 (Stage 2) and finally to a maximum of 1758 (Stage 3). The percentage increase in both the stages, i.e. Stage 1 and 2 and Stage 2 and 3 is 257.14% and 251.60%. Within Stage 1, the rate of growth of practitioners is very slow. It has increased from 96 (1800–1880) to 140 (1800–1910), the percentage increase being 45.83%. Within Stage 2 and Stage 3, there has been an increase in the number of practitioners from 206 to 500 and 1218 to 1758, respectively. The percentage increase in these cases is 142.71% and 41.05%, respectively. The decline in the Stage 3 is mainly because of the World War II.

Now let us first look at the increase in the number of practitioners of Groups 3 and 4 at different stages of development of Indian physics. The practitioners of these groups have started becoming significant in Stage 2, however, they were visible in a substantial number only in Stage 3. In Group 3, the number of practitioners has increased from seven (Stage 1) to a maximum of 26 (Stage 2), and finally to a maximum of 208 (Stage 3). The percentage increase in both the stages was 271.4% and 700%, respectively. Similarly in Group 4, the number of practitioners has increased from just 1 (Stage 1) to 9 (Stage 2), and finally to a maximum of 52 (Stage 3). The percentage increase in both the cases being 800% and 477.7%, respectively.

In contrast to Groups 3 and 4, the practitioners in Groups 1 and 2 were visible in a substantial number, right from Stage 1 itself. In terms of growth, the number of practitioners in Group 1 has increased from 102 (Stage 1) to 338 (Stage 2), and finally to a maximum of 1114 (Stage 3). The percentage increase in both the cases is 231.37% and 229.58%, respectively. Similarly, in Group 2, the number of practitioners has increased from just 30 (Stage 1) to 127 (Stage 2) and finally to 484 (Stage 3). The percentage increase in both the cases was 323.33% and 281.10%.

From the above analysis, it is concluded that the rate of growth of contributors in Groups 3 and 4 is much faster than in Groups 1 and 2. Such a trend indicates that the Indian physics as a speciality is still growing. There is no immediate saturation visible in the growth of the Indian physics publications. This is also depicted clearly in the application of technology diffusion model to the growth of Indian physics output, where parameters of the model do not indicate any saturation level in the near future.

Based on the above analysis, the following conclusions are drawn:

A systematic trend has been observed in the growth of Indian and World physics literature from 1900 to 1950. When different technology diffusion models were tried for their goodness-of-fit in the growth of Indian and World physics literature, it was observed that the best fit was obtained in terms of parameter values, fit statistics, and graphical fit to the data in case of a modified exponential diffusion technology model.

No systematic trend was observed in the applicability of two forms of Lotka's Law and negative binomial distribution in the cumulative author productivity data, representing different phases of development of Indian physics. Both of these distributions were however, found to be applicable only in few cases at the initial stages of the development of Indian physics. These results are in contrast to the hypothesis set in the present paper. Lotka's law should have found a better applicability only at the later stage of development of Indian physics, when it is more developed and matured.

As the Indian physics speciality develops and matures with time, we should expect increase in concentration in its author productivity data (as reflected in Gini index) with time. Simultaneously, the inequality between more productive and less productive scientists should increase (as measured in terms of α value). The present study clearly indicates a strong relationship between the inequality/concentration measures and the development of Indian physics as a speciality.

As expected, 80/20 rule is also found to be closely applicable in the author productivity data. The contributions made by 20% of the total number of authors in Indian physics are found to have increased from 60% (during 1980–1890) to 70% (during 1800–1950), indicating a systematic increase with time. We may also expect the contributions by 20% of total number of authors to increase and reach around 80%, as the Indian physics further develops. Price Square Root Law on the other hand is not found to be applicable. The contribution by square root of the total number of authors is much below 50% and does not show any systematic increase over time.

The paper also studied the increase in the number of practitioners at different productivity levels, highlighting their rate of growth in different phases of development of Indian physics. The four groups of authors identified on the basis of their productivity have shown different rates of growth in various time periods. Groups 1 and 2 (with floating population or low productivity), were visible from the Stage 1 onwards and showed large absolute number with high growth rates in the initial stages, but slowed down in the later phases. On the other hand, the authors of Groups 3 and 4, considered as major contributors of ideas in the speciality, were visible from Stage 2 onwards and became significant in large numbers only in Stage 3. Their absolute number and rate of growth were slow in the initial stages, but significantly increased in the third stage. Such a trend in the productivity of Indian physicists suggests that the Indian physics as a speciality is still growing and there is no immediate saturation visible in the growth of Indian physics as a speciality. This is also clearly depicted by the application of technology diffusion model where the model parameters obtained indicate no immediate saturation in the growth of Indian physics literature. The results of the study suggest that literature growth models and author productivity patterns can throw some interesting insight on the developments of a research speciality.

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