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Modeling the Growth of Neurology Literature

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ABSTRACT

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, etc. The present study demonstrates the growth of neurology literature for the period 1961-2010. A total of 291,702 records were extracted from the Science Direct Database for fifty years. The Relative Growth Rate (RGR) and Doubling Time (Dt.) of neurology literature have been calculated, supplementing with different growth patterns to check whether neurology literature fits exponential, linear, or logistic models. The results of the study indicate that the growth of literature in neurology does not follow the linear, or logistic growth 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.

Keywords: Exponential Model, Growth Models, Linear Model, Logistic Model, Modeling, Neurology, Relative Growth Rate, Scientometrics

1. INTRODUCTION

One of the features of modern research in recent years has been the spectacular development of scientific discoveries and growth of knowledge, say Gupta et al. (2002). This has caused an unprecedented accumulation of information and has become a major concern for scientists and researchers (Meera & Sangam, 2010).

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Hence, there is a need to study the growth of scientific knowledge and its dynamics in every field of activity.

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, 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. Price (1966 & 1975) was one of the pioneering researchers who studied the growth of science and found that the exponential model holds well with high accuracy in the majority of growth data of publications. The fitting of growth models, distributions, and curves to the data on exponentially growing literature and identifying the best fitting one to explain the growth of literature is an important aspect of growth study. The present study is aimed to study the growth of neurology literature published in the Science Direct database.

2. REVIEW OF LITERATURE

The understanding of the process of growth of knowledge in research specialties and its modeling has challenged bibliometricians and sociologists for a long time, say Gupta et al. (1997). Gilberts' (1978) work reveals the existing literature on the indicators of growth of knowledge in scientific specialties and lists many ways of measuring it. The analysis of Gupta et al. (1999) suggests that the growth of Indian physics literature follows a logistic model, while the growth of world physics literature is explained by the combination of logistic and power models.

Seetharam and Ravichandra Rao (1999) in their work compare trends in the growth of Food Science and Technology (FST) literature produced by CFTRI scientists, by food scientists in India, and by food scientists of the world, covering a period between 1950 and 1990. 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. The selected growth models are applied to the cumulative growth of publications and authors in theoretical population genetics from 1907-1980. It is concluded that the power model is observed to be the only model among the models studied which best explains the cumulative growth of publication and author counts in theoretical population genetics.

Karki et al. (2000) investigate Indian Organic Chemistry research activity during 1971-1989 using Chemical Abstracts. The authors conclude that the growth trends for India and world for organic chemistry follow the same patterns and the output in the three sub-fields is not going to saturate in the near future. Gupta et al. (2002) apply selected growth models to the growth of publications in six sub-disciplines of social sciences, namely economics, history, political science, psychology, and sociology in the world. The results show that the power model ($\alpha>0$, $\gamma>1$) followed by logistic models are best describing the cumulative growth of publications in all sub-disciplines. Both power and logistic models are applicable: the power model (as reflected in trend values of $\alpha 1$) and logistic model (as reflected in trend values of $\alpha 2$) in the case of cumulative growth of publications in history, political sciences, and psychology.

Tsay (2008) explores the characteristics of hydrogen energy literature from 1965-2005 based on the database of Science Citation Index Expanded (SCIE). The study reveals that the cumulative literature on hydrogen energy may be fitted relatively well by an exponential fit. Szydlowski and Krawiec (2009) present a description of knowledge more realistic than simple exponential growth. The study also reveals that the data on symbolic logic exhibit an exponential trend with some periodic oscillation. Ramakrishna (2009) examines the growth of references over the past fifteen years (1994-2008). The results show that the linear growth model provides better fits to the observed data, whereas the exponential model provided the poorest fit.

Sangam et al. (2010) study the growth and dynamics of Indian and Chinese publications in the field of liquid crystals research (1997-2006) by applying growth models as suggested by Egghe and Ravichandra Rao (1992). The authors conclude that these power and growth models are likely to be fully applicable in the growth of Indian, and linear, power, and growth models applicable in the growth of Chinese liquid crystals literature. Bouabid (2011) proposes a model which is proved to be suitable to represent observed citation distribution over time and to interestingly identify with accuracy when the major loss of citations happens. The model fits the observed data from Science Citation Index (SCI) according to R^2 which is greater than 98.9 %. Zhao and Guan (2012) assess the dynamic associations between scientific activity and technological output. The authors use the simultaneous equations model to analyze the reciprocal dependence between science and technology. The result shows that there is no significant connection between R&D expenditures and actual practices of research in terms of publications.

3. OBJECTIVES OF THE STUDY

The specific objectives of the study are

1. to study the growth of neurology literature (RGR) and also compare the growth rate as reflected in the Science Direct database among the world, China, and India.
2. to examine the Doubling Time (Dt.) of the neurology literature.
3. to analyze the fit of neurology literature for cumulative numbers of publications in terms of different models.

4. DATA AND METHODOLOGY

The dataset was collected from the Science Direct database for the period 1961-2010. A total of 291,702 records were received for fifty years. Science Direct is one of the most comprehensive database covering all subjects. Most of the research output on neurology is covered under the Science Direct Database. Hence, the same database is selected as a source for the present study. The keyword 'neurology' has been used for extracting the number of records available in the said database. The retrieved records were examined, classified, and analyzed keeping the objectives in view. Further, the data is analyzed using MS Excel spreadsheet and SPSS software (15th version). Relative Growth Rate (RGR) and Doubling Time (Dt.) of neurology literature have been calculated, supplementing with different growth patterns to check whether the neurology literature is fit for exponential, linear, or logistic models.

Relative Growth Rate (RGR) and Doubling Time (Dt.)

The Relative Growth Rate (RGR) is the increase in number of articles / pages per unit of time. This definition is derived from the definition of relative growth rates in the study of growth analysis of individual plants and is effectively applied in the field of botany (Hunt, 1978 & 1982; Poorter & Garnier, 1996; Hoffmann & Poorter, 2002). The mean Relative Growth Rate (RGR) over the specific period of interval can be calculated from the following equation:

$$1\text{-}2\ R = \frac{\log_{e\,2} W - \log_{e\,1} W}{2^T - 1^T}$$

Whereas

1-2 R = mean relative growth rate over the specific period of interval

$\log_{e\,1} W$ = log of initial number of articles

$\log_{e\,2} W$ = log of final number of articles after a specific period of interval

$2^T - 1^T$ = the unit difference between the initial time and the final time

Doubling Time (Dt.)

There exists a direct equivalence between the relative growth rate and the doubling time (Bradford, 1934). If the number of articles / pages of a subject double during a given period then the difference between the logarithms of numbers at the beginning and end of this period must be logarithms of 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 by the formula;

$$\text{Doubling Time (Dt.)} = \frac{0.693}{R}$$

5. RESULTS AND DISCUSSION

5.1. Year Wise Distribution of Literature (1961-2010)

Table 1 depicts the year wise distribution of papers in neurology literature. The world output in neurology literature is 286,001 (98.05 %) records and that of China is 3,730 (1.28 %), followed by India with 1,971 (0.68 %) records. A total of 291,702 records were extracted from the database for the period 1961-2010. It is observed that there is a steady growth of publications for world (except 1997) and China. A fluctuating trend was observed for India during the study period. An average of 5,720 papers were published per year at the global level, followed by China's average at 74 and India's average at 39. The maximum world contribution is observed during 2009 (20,656 publications) and those of China and India were published during 2010 (769 and 219, respectively). China took 24 years to achieve double digit numbers of publications, whereas India took twelve years to achieve the same. However, China took only 20 years to achieve three-digit numbers of publications but India took 33 years to achieve the same. The Relative Growth Rate (RGR) and Doubling Time (Dt.) of China, India, and world is calculated and presented in successive tables.

Table 1. Year-Wise Distribution of Literature (1961-2010)

Sl. No.	Year	World		India		China		Total	
		No. of articles	Percentage	No. of articles	Percentage	No. of articles	Percentage	No. of articles	Percentage
1	1961	400	0.14	5	0.26	0	0	405	0.14
2	1962	395	0.14	2	0.11	0	0	397	0.14
3	1963	473	0.17	4	0.21	0	0	477	0.17
4	1964	624	0.22	2	0.11	0	0	626	0.22
5	1965	709	0.25	2	0.11	1	0.03	712	0.25
6	1966	673	0.24	1	0.06	0	0	674	0.24
7	1967	783	0.28	0	0	1	0.03	784	0.27
8	1968	870	0.31	4	0.21	0	0	874	0.3
9	1969	926	0.33	6	0.31	0	0	932	0.32
10	1970	1,083	0.38	4	0.21	1	0.03	1,088	0.38
11	1971	1,169	0.41	5	0.26	3	0.09	1,177	0.41
12	1972	1,212	0.43	9	0.46	2	0.06	1,223	0.42
13	1973	1,351	0.48	10	0.51	1	0.03	1,362	0.47
14	1974	1,428	0.5	9	0.46	1	0.03	1,438	0.5
15	1975	1,682	0.59	12	0.61	0	0	1,694	0.59
16	1976	1,790	0.63	11	0.56	1	0.03	1,802	0.62
17	1977	1,846	0.65	11	0.56	0	0	1,857	0.64
18	1978	2,046	0.72	9	0.46	1	0.03	2,056	0.71
19	1979	2,168	0.76	10	0.51	4	0.11	2,182	0.75

20	1980	2,488	0.87	13	0.66	4	0.11	2,505	0.86
21	1981	2,839	1.00	18	0.92	3	0.09	2,860	0.99
22	1982	3,264	1.15	13	0.66	6	0.17	3,283	1.13
23	1983	3,535	1.24	15	0.77	6	0.17	3,556	1.22
24	1984	3,567	1.25	21	1.07	8	0.22	3,596	1.24
25	1985	3,962	1.39	18	0.92	17	0.46	3,997	1.38
26	1986	4,110	1.44	16	0.82	12	0.33	4,138	1.42
27	1987	4,708	1.65	25	1.27	13	0.35	4,746	1.63
28	1988	4,496	1.58	25	1.27	15	0.41	4,536	1.56
29	1989	4,852	1.7	19	0.97	16	0.43	4,887	1.68
30	1990	5,397	1.89	18	0.92	21	0.57	5,436	1.87
31	1991	5,696	2.00	25	1.27	22	0.59	5,743	1.97
32	1992	6,106	2.14	21	1.07	22	0.59	6,149	2.11
33	1993	5,708	2.00	30	1.53	27	0.73	5,765	1.98
34	1994	6,904	2.42	36	1.83	26	0.7	6,966	2.39
35	1995	6,842	2.4	36	1.83	32	0.86	6,910	2.37
36	1996	7,442	2.61	43	2.19	29	0.78	7,514	2.58
37	1997	11,698	4.1	44	2.24	39	1.05	11,781	4.04
38	1998	7,847	2.75	50	2.54	39	1.05	7,936	2.73
39	1999	8,207	2.87	39	1.98	68	1.83	8,314	2.86
40	2000	8,964	3.14	62	3.15	56	1.51	9,082	3.12
41	2001	8,692	3.04	45	2.29	69	1.85	8,806	3.02
42	2002	9,388	3.29	65	3.3	82	2.2	9,535	3.27
43	2003	11,374	3.98	71	3.61	131	3.52	11,576	3.97
44	2004	12,586	4.41	93	4.72	153	4.11	12,832	4.4
45	2005	15,115	5.29	89	4.52	203	5.45	15,407	5.29
46	2006	15,153	5.3	149	7.56	271	7.27	15,573	5.34
47	2007	16,366	5.73	163	8.27	420	11.27	16,949	5.82
48	2008	17,183	6.01	165	8.38	529	14.19	17,877	6.13
49	2009	20,656	7.23	209	10.61	606	16.25	21,471	7.37
50	2010	19,228	6.73	219	11.12	769	20.62	20,216	6.94
	Total	**286,001 (98.05)**	100	**1,971 (0.68)**	100	**3,730 (1.28)**	100	**291,702 (100)**	100

Table 2. Descriptive Statistics of Neurology Literature

Descriptive Statistics	*World*	*India*	*China*
Mean	5,720	39.42	74.6
Standard Error	766.51	7.5276	23.212
Standard Deviation	5420	53.228	164.13
Range	20,261	219	769
Minimum	395	0	0
Maximum	20,656	219	769
Confidence Level (95.0%)	1,540.4	15.127	46.646
Kurtosis	**0.635**	**4.098**	**8.622**
Skewness	**1.205**	**2.162**	**2.976**

5.2. Relative Growth Rate (RGR) and Doubling Time (Dt.) (India)

The Relative Growth Rate (RGR) and Doubling Time (Dt.) of publications in India have been presented in Table 3. It indicates that the value of Relative Growth Rate (RGR) of publications decreased from 0.337 in the year 1962 to 0.119 in 2010. Simultaneously, the values of Doubling Time (Dt.) increased from 2.056 in 1962 to 5.823 in 2010. It is evident from the study that research in the field of neurology in India has increased over a period of time.

5.3. Relative Growth Rate (RGR) and Doubling Time (Dt.) (China)

The Relative Growth Rate (RGR) and Doubling Time (Dt.) of publications in China have been presented in Table 4. The study reveals that the value of RGR of publications decreased from 0.693 in 1967 to 0.231 in the year 2010. However, the values of Doubling Time (Dt.) increased from 1.00 in 1967 to 3.00 in 2010. It is also observed from the study that research in the field of neurology in China has increased over a period of time.

6. GROWTH MODELS OF NEUROLOGY LITERATURE

The authors briefly introduce three growth models, viz. the Linear Growth Model, the Exponential Growth Model, and the Logistic Growth Model, which are generally used in the literature for analyzing the growth of literature in different subjects.

6.1. Linear Growth Model

The Linear Growth Model describes growth to be constant or similar from year to year. Thus, a graphic representation of the yearly data accumulated would be a straight line.

Hypothesis 1

The growth of publications in the field of neurology literature follows the Linear Growth Model.

Testing of Hypothesis

To find out the growth pattern in the field of neurology literature, publications over the last fifty years (1961-2010) were considered as a sample for the analysis in order to fit the data to test whether the growth of literature in neurology follows the Linear Growth pattern or not. The expected numbers of publications (y) or (p) were computed using the following formula:

$Y= a+b^x$

Where a and b are constants

X is the unit of time

Inference

The results of a Chi-Square test of goodness of fit

Table 3. Relative Growth Rate (RGR) and Doubling Time (Dt.) (India)

Sl. No.	Year	No. of publications	Cumulative no. of publications	W 1	W 2	RGR	Dt. (P)
1	1961	05	05		1.609		
2	1962	02	07	1.609	1.946	0.337	2.056
3	1963	04	11	1.946	2.398	0.452	1.533
4	1964	02	13	2.398	2.565	0.167	4.149
5	1965	02	15	2.565	2.708	0.143	4.846
6	1966	01	16	2.708	2.772	0.064	10.828
7	1967	00	16	2.772	2.772	0.000	00.00
8	1968	04	20	2.772	2.995	0.223	3.107
9	1969	06	26	2.995	3.258	0.263	2.635
10	1970	04	30	3.258	3.401	0.143	4.846
11	1971	05	35	3.401	3.555	0.154	4.500
12	1972	09	44	3.555	3.784	0.229	3.026
13	1973	10	54	3.784	3.988	0.204	3.397
14	1974	09	63	3.988	4.143	0.155	4.471
15	1975	12	75	4.143	4.317	0.174	3.982
16	1976	11	86	4.317	4.454	0.137	5.058
17	1977	11	97	4.454	4.574	0.120	5.775
18	1978	09	106	4.574	4.663	0.089	7.786
19	1979	10	116	4.663	4.753	0.090	7.700
20	1980	13	129	4.753	4.859	0.106	6.537
21	1981	18	147	4.859	4.990	0.131	5.290
22	1982	13	160	4.990	5.075	0.085	8.153
23	1983	15	175	5.075	5.164	0.089	7.786
24	1984	21	196	5.164	5.278	0.114	6.078
25	1985	18	214	5.278	5.366	0.088	7.875
26	1986	16	230	5.366	5.438	0.072	9.625
27	1987	25	255	5.438	5.541	0.103	6.728
28	1988	25	280	5.541	5.634	0.093	7.451
29	1989	19	299	5.634	5.700	0.066	10.500
30	1990	18	317	5.700	5.759	0.059	11.745
31	1991	25	342	5.759	5.835	0.076	9.118
32	1992	21	363	5.835	5.894	0.059	11.745
33	1993	21	384	5.894	5.950	0.056	12.375

34	1994	30	414	5.950	6.026	0.076	9.118
35	1995	36	450	6.026	6.109	0.083	8.349
36	1996	43	493	6.109	6.200	0.091	7.615
37	1997	44	537	6.200	6.200	0.086	8.058
38	1998	50	587	6.286	6.375	0.089	7.786
39	1999	39	626	6.375	6.439	0.064	10.828
40	2000	62	688	6.439	6.534	0.095	7.294
41	2001	45	733	6.534	6.597	0.063	11.000
42	2002	65	798	6.597	6.682	0.085	8.153
43	2003	71	869	6.682	6.767	0.085	8.153
44	2004	93	962	6.767	6.869	0.102	6.794
45	2005	89	1,051	6.869	6.957	0.088	7.875
46	2006	149	1,200	6.957	7.090	0.133	5.210
47	2007	163	1,363	7.090	7.217	0.127	5.456
48	2008	165	1,528	7.217	7.332	0.115	6.026
49	2009	209	1,737	7.332	7.459	0.127	5.456
50	2010	219	1,956	7.459	7.578	0.119	5.823

Table 4. Relative Growth Rate (RGR) and Doubling Time (Dt.) (China)

Sl. No.	Year	No. of publications	Cumulative no. of publications	W 1	W 2	RGR	Dt. (P)
1	1961	00	00		00		
2	1962	00	00	00	00	00	00
3	1963	00	00	00	00	00	00
4	1964	00	00	00	00	00	00
5	1965	01	01	00	00	00	00
6	1966	00	01	00	00	00	00
7	1967	01	02	00	0.693	0.693	1.00
8	1968	00	02	0.693	0.693	00	00
9	1969	00	02	0.693	0.693	00	00
10	1970	01	03	0.693	1.098	0.405	1.711
11	1971	03	06	1.098	1.791	0.693	1.00
12	1972	02	08	1.791	2.079	0.288	2.406
13	1973	01	09	2.079	2.197	0.118	2.406
14	1974	01	10	2.197	2.302	0.105	6.600

15	1975	00	10	2.302	2.302	00	00
16	1976	01	11	2.302	2.397	0.095	7.294
17	1977	00	11	2.397	2.397	00	00
18	1978	01	12	2.397	2.485	0.088	7.875
19	1979	04	16	2.485	2.772	0.287	2.414
20	1980	04	20	2.772	2.995	0.223	3.107
21	1981	03	23	2.995	3.135	0.140	4.950
22	1982	06	29	3.135	3.367	0.232	2.987
23	1983	06	35	3.367	3.555	0.188	3.686
24	1984	08	43	3.555	3.761	0.206	3.364
25	1985	17	60	3.761	4.094	0.333	2.081
26	1986	12	72	4.094	4.276	0.182	2.807
27	1987	13	85	4.276	4.442	0.166	4.174
28	1988	15	100	4.442	4.605	0.163	4.251
29	1989	16	116	4.605	4.753	0.148	4.682
30	1990	21	137	4.753	4.919	0.166	4.174
31	1991	22	159	4.919	5.068	0.149	4.651
32	1992	22	181	5.068	5.198	0.130	5.330
33	1993	27	208	5.198	5.337	0.139	4.985
34	1994	26	234	5.337	5.455	0.118	5.872
35	1995	32	266	5.455	5.583	0.128	5.414
36	1996	29	295	5.583	5.687	0.104	6.663
37	1997	39	334	5.687	5.811	0.124	5.588
38	1998	39	373	5.811	5.921	0.110	6.300
39	1999	68	441	5.921	6.089	0.168	4.125
40	2000	56	497	6.089	6.208	0.119	5.823
41	2001	69	566	6.208	6.338	0.130	5.330
42	2002	82	648	6.338	6.474	0.136	5.095
43	2003	131	779	6.474	6.658	0.184	3.766
44	2004	153	932	6.658	6.837	0.179	3.871
45	2005	203	1,135	6.837	7.034	0.197	3.517
46	2006	271	1,406	7.034	7.248	0.214	3.238
47	2007	420	1,826	7.248	7.509	0.261	2.655
48	2008	529	2,355	7.509	7.764	0.255	2.717
49	2009	606	2,961	7.764	7.993	0.229	3.026
50	2010	769	3,730	7.993	8.224	0.231	3.000

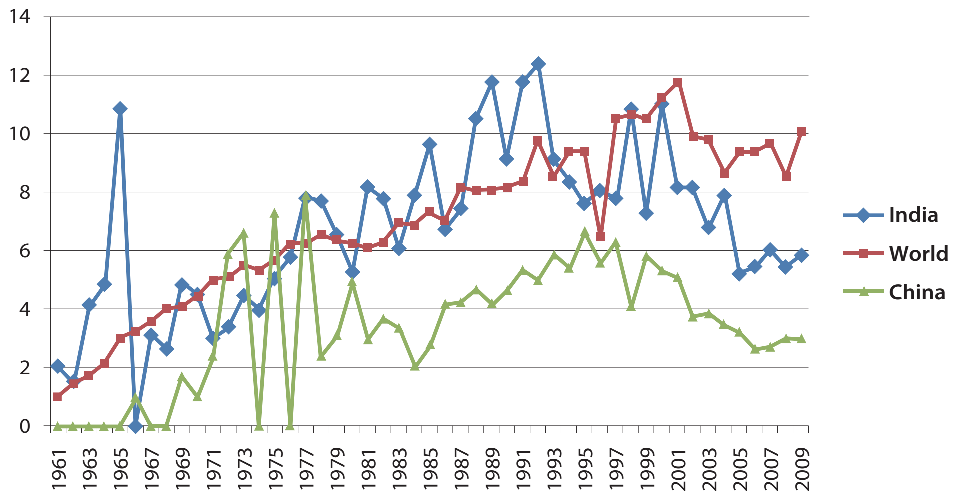

Fig. 1 Doubling time of Neurology literature

Table 5. Fit into Linear Growth of Neurology Literature

X	Year	Observed no. of publications Y (f)	XY	X^2	Expected no. of publications P Y= a+b^x	f-p	$(f-p)^2$	$\frac{(f-p)^2}{p}$
1	1961	405	405	1	-2,740.1	3,145.1	9,891,654	-3,610
2	1962	397	794	4	-2,390.2	2,787.2	7,768,484	-3,250.1
3	1963	477	1,431	9	-2,040.3	2,517.3	6,336,799	-3,105.8
4	1964	626	2,504	16	-1,690.4	2,316.4	5,365,709	-3,174.2
5	1965	712	3,560	25	-1,340.5	2,052.5	4,212,756	-3,142.7
6	1966	674	4,044	36	-990.6	1,664.6	2,770,893	-2,797.2
7	1967	784	5,488	49	-640.7	1,424.7	2,029,770	-3,168.1
8	1968	874	6,992	64	-290.8	1,164.8	1,356,759	-4,665.6
9	1969	932	8,388	81	59.1	872.9	761,954	12,892.6
10	1970	1,088	10,880	100	409	679	461,041	1,127.24
11	1971	1,177	12,947	121	758.9	418.1	174,808	230.343
12	1972	1,223	14,676	144	1,108.8	114.2	13,041.6	11.7619
13	1973	1,362	17,706	169	1,458.7	-96.7	9,350.89	6.41043
14	1974	1,438	20,132	196	1,808.6	-370.6	137,344	75.9396
15	1975	1,694	25,410	225	2,158.5	-464.5	215,760	99.9584
16	1976	1,802	28,832	256	2,508.4	-706.4	499,001	198.932
17	1977	1,857	31,569	289	2,858.3	-1,001.3	1,002,602	350.769

18	1978	2,056	37,008	324	3,208.2	-1,152.2	1,327,565	413.804
19	1979	2,182	41,458	361	3,558.1	-1,376.1	1,893,651	532.209
20	1980	2,505	50,100	400	3,908	-1,403	1,968,409	503.687
21	1981	2,860	60,060	441	4,257.9	-1,397.9	1,954,124	458.941
22	1982	3,283	72,226	484	4,607.8	-1,324.8	1,755,095	380.897
23	1983	3,556	81,788	529	4,957.7	-1,401.7	1,964,763	396.305
24	1984	3,596	86,304	576	5,307.6	-1,711.6	2,929,575	551.958
25	1985	3,997	99,925	625	5,657.5	-1,660.5	2,757,260	487.364
26	1986	4,138	107,588	676	6,007.4	-1,869.4	3,494,656	581.725
27	1987	4,746	128,142	729	6,357.3	-1,611.3	2,596,288	408.395
28	1988	4,536	127,008	784	6,707.2	-2,171.2	4,714,109	702.843
29	1989	4,887	141,723	841	7,057.1	-2,170.1	4,709,334	667.319
30	1990	5,436	163,080	900	7,407	-1,971	3,884,841	524.482
31	1991	5,743	178,033	961	7,756.9	-2,013.9	4,055,793	522.863
32	1992	6,149	196,768	1,024	8,106.8	-1,957.8	3,832,981	472.811
33	1993	5,765	190,245	1,089	8,456.7	-2,691.7	7,245,249	856.747
34	1994	6,966	236,844	1,156	8,806.6	-1,840.6	3,387,808	384.69
35	1995	6,910	241,850	1,225	9,156.5	-2,246.5	5,046,762	551.167
36	1996	7,514	270,504	1,296	9,506.4	-1,992.4	3,969,658	417.577
37	1997	11,781	435,897	1,369	9,856.3	1,924.7	3,704,470	375.848
38	1998	7,936	301,568	1,444	10,206.2	-2,270.2	5,153,808	504.968
39	1999	8,314	324,246	1,521	10,556.1	-2,242.1	5,027,012	476.219
40	2000	9,082	363,280	1,600	10,906	-1,824	3,326,976	305.059
41	2001	8,806	361,046	1,681	11,255.9	-2,449.9	6,002,010	533.232
42	2002	9,535	400,470	1,764	11,605.8	-2,070.8	4,288,213	369.489
43	2003	11,576	497,768	1,849	11,955.7	-379.7	144,172	12.0589
44	2004	12,832	564,608	1,936	12,305.6	526.4	277,097	22.518
45	2005	15,407	693,315	2,025	12,655.5	2,751.5	7,570,752	598.218
46	2006	15,573	716,358	2,116	13,005.4	2,567.6	6,592,570	506.91
47	2007	16,949	796,603	2,209	13,355.3	3,593.7	1.30E+07	967.008
48	2008	17,877	858,096	2,304	13,705.2	4,171.8	1.70E+07	1,269.88
49	2009	21,471	1,052,079	2,401	14,055.1	7,415.9	5.50E+07	3,912.86
50	2010	20,216	1,010,800	2,500	14,405	5,811	3.40E+07	2,344.17

$a = -3{,}090$, $b = 349.9$, $X^2 = 10{,}094.5$

For India: $a = -33.25$, $b = 2.85$, $X^2 = 408.399$
For China: $a = -108.9$, $b = 7.199$, $X^2 = 2{,}982.08$

indicated that the calculated Chi-Square value (X^2= 10,094.5) is much higher than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at 0.05 (5%) level of significance. Hence, Hypothesis 1 has been rejected and it is concluded that the growth of literature in neurology does not follow the Linear Growth Model. Similar Growth Models have also been calculated for China and India. In both cases the calculated Chi-Square values (X^2= 408.399 for India, X^2 = 2,982.08 for China) are much more than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at 0.05 (5%) level of significance. In both cases the growth of literature in neurology does not follow the Linear Growth Model. The application of the Linear Growth Model in terms of R^2 (0.854) is shown in Fig. 2. The fit statistics indicate a poor fit for the Linear Growth Model in the data sets. A graphical presentation of observed and estimated data values obtained is also shown in Fig. 2.

6.2. Exponential Growth Model

The Exponential Growth Model describes an unlimited exponential growth. This model not only provides a rate of growth (the exponential parameter) but also the rate at which the size of the literature doubles, and its doubling time. The exponential growth has been linked to compound interest.

Hypothesis 2

The growth of publications in the field of neurology literature better fit the Exponential Growth Model.

Testing of Hypothesis

In order to fit the data to test whether the growth of literature in neurology follows the exponential growth pattern or not, the expected number of publications (y) were computed using the following formula:

$Y= K+ab^x$

Where a and b are constants

K= is the asymptote or the upper limit

X is the unit of time

Inference

The results of a Chi-Square test of goodness of fit indicated that the calculated Chi-Square value is (X^2= 3,631.96), higher than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at 0.05 level of significance. Hence, Hypothesis 2 has been rejected

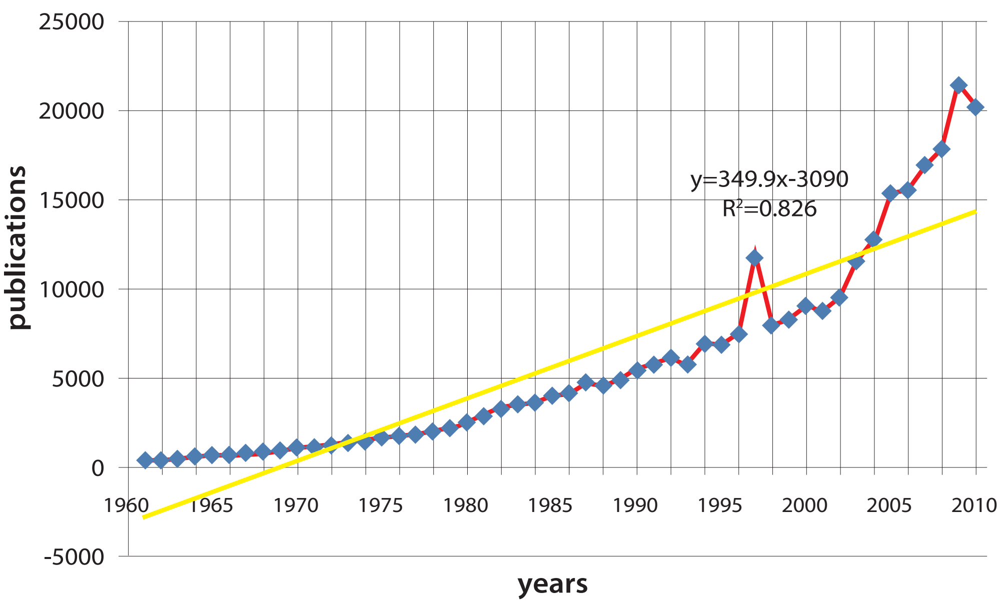

Fig. 2 Linear growth pattern of neurology literature

and it is concluded that the growth of literature in neurology does not exactly follow the Exponential Growth Model. The Exponential Growth model was also applied for China and India. In both cases the calculated Chi-Square value (X^2= 100.9477 for India, and X^2 = -5,017.79 for China) is greater than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at 0.05 (5%) level of significance. In both cases, the growth of literature in neurology does not exactly follow the Exponential Growth Model. However, it nearly follows this growth model.

However, the application of the Exponential Growth Model in terms of R^2 (0.984) is shown in Fig. 3. The fit statistics indicate that it nearly follows the Exponential Growth Model in the data sets. A graphical presentation of observed and estimated data values obtained is also shown in Fig. 3.

6.3. Logistic Growth Model

Hypothesis 3

The growth of publications in the field of neurology literature follows the Logistic Growth Model.

Testing of Hypothesis

In order to fit the data to test whether the growth

Table 6. Fit into Exponential Growth of Neurology Literature

X	Year	Observed no. of publications Y (f)	Expected no. of publication $Y=K+ab^x$	f-p	$(f-p)^2$	$\frac{(f-p)^2}{p}$
1	1961	405	273.27	131.73	17,354	63.505
2	1962	397	357.12	39.883	1,590.7	4.4542
3	1963	477	445.31	31.694	1,004.5	2.2557
4	1964	626	538.06	87.941	7,733.7	14.373
5	1965	712	635.61	76.39	5,835.4	9.1807
6	1966	674	738.21	-64.21	4,122.9	5.5849
7	1967	784	846.12	-62.12	3,858.5	4.5603
8	1968	874	959.61	-85.61	7,328.8	7.6373
9	1969	932	1,079	-147	21,601	20.02
10	1970	1,088	1,204.5	-116.5	13,575	11.27
11	1971	1,177	1,336.5	-159.5	25,455	19.045
12	1972	1,223	1,475.4	-252.4	63,712	43.183
13	1973	1,362	1,621.5	-259.5	67,322	41.519
14	1974	1,438	1,775.1	-337.1	113,618	64.008
15	1975	1,694	1,936.6	-242.6	58,869	30.398
16	1976	1,802	2,106.5	-304.5	92,748	44.029
17	1977	1,857	2,285.3	-428.3	183,401	80.254
S1=		17,522				
18	1978	2,056	2,473.2	-417.2	174,062	70.379
19	1979	2,182	2,670.9	-488.9	239,011	89.487

20	1980	2,505	2,878.8	-373.8	139,723	48.535
21	1981	2,860	3,097.5	-237.5	56,387	18.204
22	1982	3,283	3,327.4	-44.44	1,974.8	0.5935
23	1983	3,556	3,569.3	-13.32	177.37	0.0497
24	1984	3,596	3,823.7	-227.7	51,853	13.561
25	1985	3,997	4,091.3	-94.27	8,886.6	2.1721
26	1986	4,138	4,372.7	-234.7	55,070	12.594
27	1987	4,746	4,668.6	77.37	5,986.1	1.2822
28	1988	4,536	4,979.9	-443.9	197,051	39.569
29	1989	4,887	5,307.3	-420.3	176,639	33.282
30	1990	5,436	5,651.6	-215.6	46,485	8.2251
31	1991	5,743	6,013.7	-270.7	73,299	12.189
32	1992	6,149	6,394.6	-245.6	60,324	9.4336
33	1993	5,765	6,795.2	-1,030	1E+06	156.18
34	1994	6,966	7,216.5	-250.5	62,748	8.6951
S2=		**72,401**				
35	1995	6,910	7,659.6	-749.6	561,901	73.359
36	1996	7,514	8,125.6	-611.6	374,094	46.039
37	1997	11,781	8,615.8	3,165.2	1E+07	1162.8
38	1998	7,936	9,131.3	-1,195	1E+06	156.46
39	1999	8,314	9,673.5	-1,359	2E+06	191.05
40	2000	9,082	10,244	-1,162	1E+06	131.74
41	2001	8,806	10,843	-2,037	4E+06	382.82
42	2002	9,535	11,474	-1,939	4E+06	327.74
43	2003	11,576	12,138	-561.6	315,402	25.986
44	2004	12,832	12,835	-3.338	11.145	0.0009
45	2005	15,407	13,569	1,837.8	3E+06	248.92
46	2006	15,573	14,341	1,232	2E+06	105.84
47	2007	16,949	15,153	1,796.3	3E+06	212.94
48	2008	17,877	16,006	1,870.6	3E+06	218.6
49	2009	21,471	16,904	4,566.6	2E+07	33.7
50	2010	20,216	17,849	2,367.3	6E+06	313.97
S3=		**201,779**				3,631.96

a= 1,540.841, b= 1.051742, K = -1,347.3, X^2=3,631.96

For India: a= 0.77, b= 1.115, K= 3.55, X^2= 100.9477

For China: a=-0.1768, b= 1.174, K= -160, X^2= -5,017.79

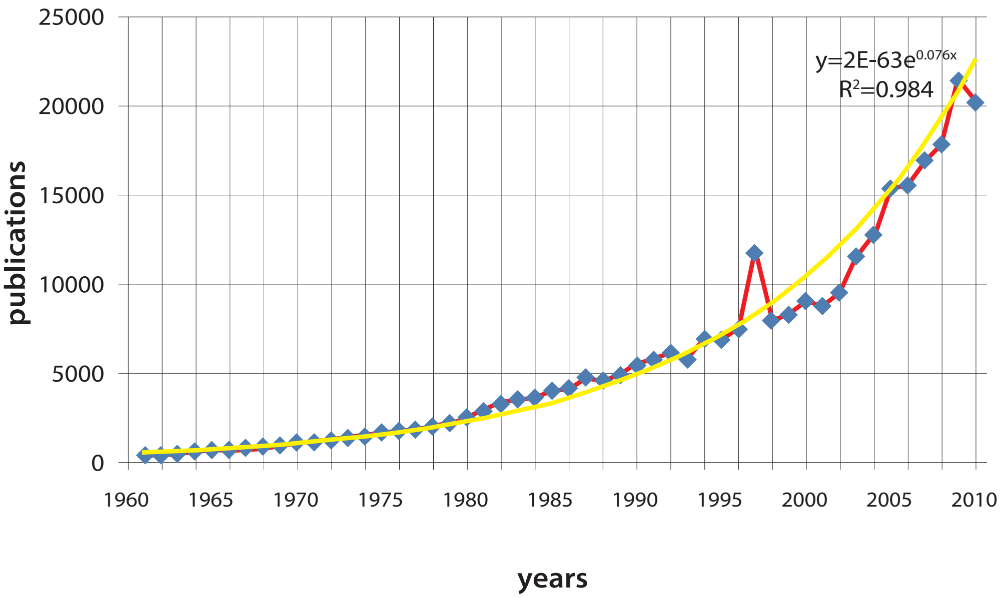

Fig. 3 Expontial Growth Pattern of Neurology Literature

of literature in neurology follows the logistic growth pattern or not, the expected number of publications (y) were computed using the following formula:

$1/Y= K+ab^x$

Where a and b are constants

K= is the asymptote or the upper limit

X is the unit of time

Inference

The results of the Chi-Square test of goodness of fit show that the calculated Chi-Square value is (X^2= 5,821.7), much higher than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at .05 level of significance. Hence, Hypothesis 3 has been rejected and it is concluded that the growth of literature in neurology does not follow the Logistic Growth Model.

The Logistic Growth model was also applied for China and India. In both cases the calculated Chi-Square value (X^2= 199.669504 for India, X^2 = -89,291.47204 for China) is much greater than the critical Chi-Square value of 31.41 for 49 degrees of freedom (*df*) at 0.05 (5%) level of significance. In both cases the growth of literature in neurology does not follow the Logistic Growth Model.

7. CONCLUSION

The bibliometric technique is considered as the most powerful technique for conducting such quantitative studies in this direction. An attempt was made in the present study to measure the trends in various aspects of published literature in the field of neurology literature.

The study is based on 291,702 research papers published between 1961-2010 as reflected in Science Direct, which is one of the most comprehensive databases covering all subjects. The data were collected, tabulated, and analyzed. The study reveals some factual factorial data through bibliometric analysis. Research articles have been analyzed for finding the year wise trend, Relative Growth Rate, Doubling Time, and examining the different types of growth rate models. The outcome of the present study shows that there is a steady growth of publications for world (except 1997) and China, and a fluctuating trend was observed for India during the study period. Averages of 5,720 papers were published per year at the global level, followed by China's average which is 74 and India's average at 39. The maximum world contribution is observed during 2009 (20,656 publications) and

Table 7. Fit into Logistic Growth of Model of Neurology Literature

X	Year	Y	1/Y	Expected no. of publications $1/Y=K+ab^x$	f-p	$(f\text{-}p)^2$	$\frac{(f-p)^2}{p}$
1	1961	405	0.00247	469.089	-64.0894	4,107.44948	8.756219
2	1962	397	0.00252	516.22	-119.22	14,213.31824	27.53347
3	1963	477	0.0021	567.969	-90.9688	8,275.322192	14.57003
4	1964	626	0.0016	624.765	1.234815	1.524767453	0.002441
5	1965	712	0.0014	687.072	24.92833	621.4217341	0.90445
6	1966	674	0.00148	755.387	-81.3875	6,623.919766	8.768903
7	1967	784	0.00128	830.25	-46.2497	2,139.03512	2.576376
8	1968	874	0.00114	912.235	-38.2347	1,461.895382	1.602543
9	1969	932	0.00107	1,001.96	-69.9592	4,894.290061	4.88472
10	1970	1,088	0.00092	1,100.08	-12.0806	145.9408986	0.132664
11	1971	1,177	0.00085	1,207.3	-30.2974	917.9336117	0.760321
12	1972	1,223	0.00082	1,324.35	-101.349	10,271.5322	7.755913
13	1973	1,362	0.00073	1,452.01	-90.012	8,102.16351	5.579956
14	1974	1,438	0.0007	1,591.1	-153.102	23,440.37362	14.73216
15	1975	1,694	0.00059	1,742.47	-48.468	2,349.148287	1.348173
16	1976	1,802	0.00055	1,906.99	-104.985	11,021.87541	5.779739
17	1977	1,857	0.00054	2,085.55	-228.553	52,236.28849	25.04674
	S1=		**0.02076**				
18	1978	2,056	0.00049	2,279.08	-223.083	49,766.23102	21.83607
19	1979	2,182	0.00046	2,488.5	-306.495	93,939.25715	37.74942
20	1980	2,505	0.0004	2,714.7	-209.697	43,973.00579	16.19812
21	1981	2,860	0.00035	2,958.58	-98.5786	9,717.739615	3.284597
22	1982	3,283	0.0003	3,220.99	62.01099	3,845.363017	1.193845
23	1983	3,556	0.00028	3,502.72	53.27738	2,838.479262	0.810364
24	1984	3,596	0.00028	3,804.5	-208.496	43,470.7656	11.42615
25	1985	3,997	0.00025	4,126.93	-129.928	16,881.31098	4.090527
26	1986	4,138	0.00024	4,470.51	-332.512	110,564.1821	24.73188
27	1987	4,746	0.00021	4,835.59	-89.5941	8,027.100512	1.660003
28	1988	4,536	0.00022	5,222.35	-686.347	471,072.7936	90.20327
29	1989	4,887	0.0002	5,630.75	-743.747	553,159.502	98.2391
30	1990	5,436	0.00018	6,060.55	-624.547	390,058.6262	64.3603
31	1991	5,743	0.00017	6,511.26	-768.26	590,223.1919	90.64654
32	1992	6,149	0.00016	6,982.14	-833.142	694,125.1915	99.41437

33	1993	5,765	0.00017	7,472.18	-1,707.18	2,914,460.651	390.0416
34	1994	6,966	0.00014	7,980.08	-1,014.08	1,028,367.931	128.8668
S2=			**0.00452**				
35	1995	6,910	0.00014	8,504.3	-1,594.3	2,541,791.052	298.8831
36	1996	7,514	0.00013	9,043	-1,529	2,337,848.68	258.5257
37	1997	11,781	8.50E-05	9,594.13	2,186.871	4,782,404.508	498.472
38	1998	7,936	0.00013	10,155.4	-2,219.4	4,925,724.935	485.0352
39	1999	8,314	0.00012	10,724.3	-2,410.34	5,809,752.995	541.7351
40	2000	9,082	0.00011	11,298.4	-2,216.36	4,912,247.289	434.7753
41	2001	8,806	0.00011	11,874.7	-3,068.74	9,417,189.196	793.0436
42	2002	9,535	0.0001	12,450.8	-2,915.75	8,501,603.095	682.8185
43	2003	11,576	8.60E-05	13,023.6	-1,447.64	2,095,662.483	160.9122
44	2004	12,832	7.80E-05	13,590.7	-758.732	575,673.8623	42.35783
45	2005	15,407	6.50E-05	14,149.5	1,257.547	1,581,424.085	111.7657
46	2006	15,573	6.40E-05	14,697.4	875.6138	766,699.4442	52.1657
47	2007	16,949	5.90E-05	15,232.3	1,716.694	2,947,038.897	193.4729
48	2008	17,877	5.60E-05	15,752.2	2,124.788	4,514,724.487	286.6089
49	2009	21,471	4.70E-05	16,255.4	5,215.646	27,202,963.56	1,673.477
50	2010	20,216	4.90E-05	16,740.2	3,475.753	12,080,859.21	721.6655
S3=			**0.00144**				

a= 0.002304, b= 0.960849, b^n= 0.189712, K= 0.0000424, X^2= 8,451.202

For China: a= 0.5924, b= 0.929, K= 0.03009, X^2= -89,291.47204
For India: a= 0.5113, b=0.9077, K = 0.0025, X^2= 199.669504

Table 8. Growth Models of Neurology Literature (R^2 value)

Growth models	World	China	India	Remark
Linear	**0.826**	**0.408**	**0.609**	**Not fit**
Exponential	**0.984**	**0.861**	**0.765**	**Not fit**
Logistic	**0.957**	**0.721**	**0.653**	**Not fit**

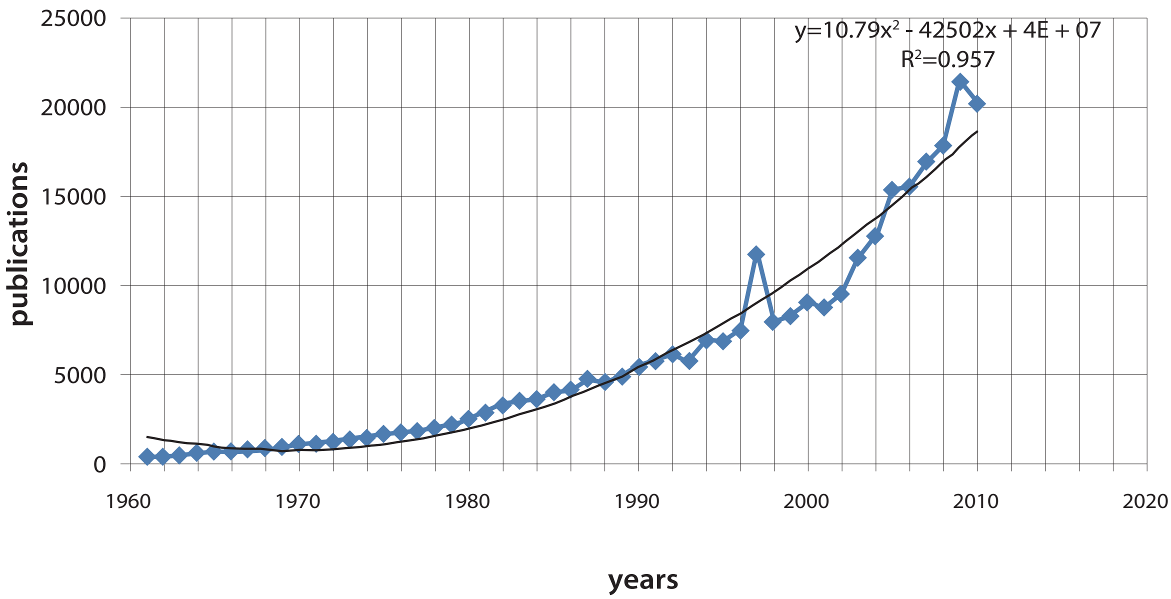

Fig. 4 Logistic Growth Model

those of China and India were published during 2010. China took 24 years to achieve double digit numbers of publications, whereas India took twelve years to achieve the same. The research in the field of neurology in India and China has increased over a period of time. The growth of literature in neurology does not follow either the Linear Growth Model or Logistic Growth Model. However, it nearly follows the Exponential Growth Model. The study concludes that there has been a consistent trend towards increased growth of literature in the field of neurology.

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