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Dependence of Lotka's law parameters on the scientific area

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ABSTRACT

The main aim of this paper was to examine whether the characteristics of the Lotka distribution of publications (in particular, the changes that the two parameters, n and c, undergo) constitute an indicator of the structure of influence in a scientific field. A quasi-experimental method was used to estimate the parameters of Lotka's law in a number of scientific areas (by means of a series of searches in the Scopus database). The study was performed on 90 sets of author productivity data (resulting from a combination of 10 areas, 14 countries, and 3 time periods). Both the exponent of the law, n (i.e., the slope of the log-log plot), and the constant c (the fraction of authors with only a single publication) were found to depend on the state of development of the scientific area, on its productivity, on the country, and on the time period being studied. A characteristic that distinguished the so-called "hard sciences" from the "social sciences and humanities" was the level of co-authorship, with the average number of authors per publication being greater in science than in the social sciences and humanities. The empirical results show a picture of the behaviour of the Lotka distribution in different situations, due to different causes. This could be interesting as a better understanding of these regularities may allow them to be incorporated into the theoretical context.

Keywords: Lotka's law; Research productivity; Publication productivity; Scientometrics; Scientific influence.

INTRODUCTION

The original article of Lotka's law was published in 1926. Lotka made a log-log plot of the percentage of authors making 1, 2, 3, ..., *n* contributions against the number of contributions. He then used the least-squares method to calculate the slope of the line, which he found to be 2.021 for physics and 1.888 for chemistry.

Overall, studies dealing with Lotka's law can be ascribed to one of two categories. The first consists of work whose focus has been to demonstrate compliance with the law among certain groups of scientists. Beginning in the 1970s, there have been many studies aimed at verifying compliance with the law in its original formulation – the inverse square law. Their results, however, have been inconclusive, and instead have served to highlight the need for methodological refinement of the analysis and verification tests. A second, quite different approach has gradually been imposing itself. Researchers have been attempting to find models that more accurately describe the productivity of authors, or methods that allow further refinement in the calculation of the parameters with more suitable tests of the goodness-of-fit (χ^2 or Kolmogorov-Smirnov). In this second type of approach, Lotka's law is recast in a form such that its original statement is simply a special case, i.e., for certain sets of documents or authors that reasonably well fit one of the expressions:

$y_x = y_1 \times x^{-2}$, as a special case;

$y_x = c \times x^{-n}$, as the general case.

In an article appearing in 1972, Vlachý observes that several variables might play a role in influencing how appropriate Lotka's law is to a given set of data (Vlachý 1972). He examined bibliographies in many subject areas, listing the number of years covered by each source, the number of papers and authors represented, and the slope of the fitted line. While the data presented are interesting, Vlachý does not attempt to test the applicability of Lotka's law, nor does he provide sufficient data for others to perform statistical tests on his data. In this and a later article, Vlachý (1976) discusses how the slope of the fitted line (author productivity) varies according to both (1) the time period under study (the number of years covered), and (2) the community of authors involved (universal, national, international). Vlachý is mainly concerned with how these two variables affect the slope of the fitted line, i.e., the exponent in Lotka's formulation, and not with the appropriateness of Lotka's law.

Wagner-Döbler and Berg (1995, p.36) make the following comment: "*So far one thing is certain: poor dynamics of a scientific area can influence the Lotka distribution in the direction of a stronger concentration (the exponent and the constant getting smaller)… Obviously, the Lotka distributions of many scientific disciplines in Pao's record depend on the state of development … The fraction of new and possibly very productive authors in the former area should be substantially smaller than in the latter one. The more intense the growth, the greater the effect. This has nothing to do with the distinction between 'hard' and 'soft' sciences considered by Pao (1986).*"

OBJECTIVES

The aim of the present work was to analyze the parameters of Lotka's distribution through a quasi-experimental approach, examining a series of scientific areas or disciplines with the following objectives:

a) To establish which are the characteristics presented by different scientific areas, based on the values of the parameters of Lotka's distribution;
b) To analyze the possible correlations between the characteristics found in the data and the Lotka's law parameters.
c) To provide a guide to the analysis and classification of different disciplines based on the value of their parameters.

MATERIALS AND METHOD

The experiment consisted of a series of searches of the Scopus database (one for each of the 10 scientific areas studied, each of these in three different countries), considering three time periods long enough for the authors to have been able to disseminate their research (2000-2004, 2005-2009, and 2000-2009). The data were exported from Scopus to an Excel spreadsheet in which they were sorted and from there to an Access database, both of Microsoft Office, for their summary in the form of tables. In each of the areas, the authors' productivity distribution was analyzed following the method proposed by Pao (1985) for the parameters *n* (exponent) and *c* (fraction of authors with only one published paper).

Since the value of the exponent can vary depending on the number of data points used to compute the regression equation, and the goal of the procedure was to find the best regression line for the data set, a maximum value of the coefficient of determination, R^2, was sought by calculating several regression lines for different cut-off points of each set of data. The coefficient R^2 is the proportion of the variation explained by the regression line (Pao 1986). The number of large producers excluded was constrained to lie between the values considered by Price (1971) and by Yablonsky (1980). All co-authors of the papers were included in the analyses.

The aim with the calculation of the Lotka law parameters was to study the characteristics of each area, and in particular to elucidate the type of relationship of these parameters with each case. The correlation analysis between the two parameters of Lotka's law and author productivity, and the analysis of variance (One Way ANOVA) between three subject disciplines (Science, Social Science and Arts & Humanities) were performed using the IBM SPSS Statistics (version 19) programme package.

RESULTS

Characteristics of Different Disciplines based on Parameter Values of Lotka's Distribution

Table 1 presents the experimental results for the 90 cases that resulted from the combination of 10 scientific areas with 3 time periods in 14 countries.

Dentistry (DENT) had greater growth in Brazil than in Spain or Germany. While all three countries showed growth, in Brazil the number of records and authors increased threefold from 2000-2004 to 2005-2009, compared with a twofold increase in the other two countries, although Germany showed high productivity. This major growth of publications in Brazil from the first to the second periods led to a reduction in the exponent and in the fraction of authors with a single publication. Dentistry is thus an area in full expansion in Brazil, and one which is highly dynamic due to its strong growth.

In contrast, the area Chemical Engineering (CENG) showed a more moderate growth than Dentistry. Productivity declined in both Spain and Israel from the first to the second periods. Growth in this area was similar in Brazil and Spain, but barely noticeable in Israel. The parameters of Lotka's law show hardly any change in Brazil or even increase as in the case of Spain and Israel.

In the area of Veterinary Medicine (VETE), Turkey presented the highest productivity, although growth was greater in Brazil and Spain. The parameters $n(t)$ and $c(t)$ increased in all three countries in the period 2005-2009, although their values were far lower in Turkey due to its high productivity.

Computer Sciences (COMP) was also an area showing major growth in the three countries studied. In Brazil, the records and authors showed a threefold increase and the authorship fourfold. In Belgium and Sweden, the increases were by factors of just over two. There was also a major increase in productivity in the three countries. As a consequence, both $n(t)$ and $c(t)$ fell in Brazil and Sweden, and remained more or less stable in Belgium.

Although Pharmacology, Toxicology, and Pharmaceutics (PHAR) is a mature, stable area, Brazil seems to be emerging with great force as reflected in a doubling of its values of

authorship and number of authors. In Spain and Sweden these values were simply maintained, with productivity actually declining in the second period. As a result, both $n(t)$ and $c(t)$ fell in the case of Brazil, but remained roughly constant in the case of Sweden and even rose in the case of Spain.

In Mathematics (MATH), there was similar growth in the three countries studied (with a doubling of the numbers of records and of authors from the first to the second periods). Productivity increased more in Sweden, however, than in Greece or Mexico. Hence, while in Greece and Mexico both $n(t)$ and $c(t)$ increased, in Sweden these two parameters fell noticeably.

The four subject areas that remain to be discussed belong to the group known as social sciences and humanities. They shared a common feature: the average number of authors per publication was less than in the areas of science. This could be the reason that the values of the exponents were generally higher than for the hard sciences.

In Economics, Econometrics, and Finance (ECON), both Spain and Sweden doubled the number of publications and authors from 2000-2004 to 2005-2009, with the corresponding behaviour of $n(t)$ and $c(t)$ being very similar to cases in the subject areas of science with similar growth rates. For China, the number of publications increased eightfold and the number of authors fivefold. Nonetheless, this was not reflected in any difference with the other two countries in the response of the value of the parameters $n(t)$ and $c(t)$. China's productivity did rise sharply between the first and second periods, however, with a much greater change than that experienced by the other two countries. This major growth may have been due to causes external to the area itself, perhaps reflecting Scopus's inclusion of a greater number of records from this country during the second period.

In Business, Management, and Accounting (BUSI), there were two distinct patterns of behaviour: Spain and France had a more than twofold growth, while India's growth was by somewhat less than a factor of two. India's productivity, however, was much higher than in the other two countries. This was reflected in high values of the parameters for Spain and France, with $n(t)$ close to 3 and $c(t)$ of around 0.8 or more, while those for India were much lower.

Social Sciences (SOCI) presented high growth rates, with Brazil quadrupling and the other two countries (Belgium and Mexico) doubling the number of their publications. Despite this, productivity was low in all cases – lower than in the previous two subject areas. The resulting parameter values, $n(t)$ and $c(t)$, were very high for all three, especially for Brazil and Mexico.

Finally, Arts and Humanities (ARTS) presented a behaviour that was similar to that of the previous subject area – low productivity, and consequently high values of the parameters $n(t)$ and $c(t)$.

Table 1: Empirical Results for Lotka's Law Parameters in Different Scientific Areas, Countries, and Time Periods

Area[a]	Country[b]	Years[c]	Records[d]	Authorship(a)[e]	Authors(b)[f]	a/b[g]	n(t)[h]	c(t)[i]	R^2(t)[j]
DENT	Brazil	2000-4	1376	5856	3134	1.87	2.57	0.7600	0.976
DENT	Brazil	2005-9	4740	23123	10260	2.25	2.20	0.6708*	0.994
DENT	Brazil	2000-9	6116	28979	11817	2.45	2.17	0.6622*	0.989
DENT	Spain	2000-4	652	2776	1703	1.63	2.38	0.7181*	0.994
DENT	Spain	2005-9	1272	6051	3262	1.85	2.39	0.7205*	0.986
DENT	Spain	2000-9	1924	8795	4362	2.01	2.38	0.7181	0.992
DENT	Germany	2000-4	1595	6513	3087	2.10	2.08	0.6345	0.984
DENT	Germany	2005-9	2874	13523	5562	2.43	2.02	0.6147	0.989
DENT	Germany	2000-9	4469	20036	7490	2.67	2.01	0.6113	0.980
CENG	Brazil	2000-4	3566	12995	7365	1.76	2.39	0.7205*	0.998
CENG	Brazil	2005-9	5652	24647	13361	1.84	2.38	0.7181	0.995
CENG	Brazil	2000-9	9218	37642	18059	2.08	2.34	0.7083	0.990
CENG	Spain	2000-4	5914	24561	10350	2.37	2.09	0.6377*	0.992
CENG	Spain	2005-9	9732	44566	19653	2.27	2.20	0.6708	0.995
CENG	Spain	2000-9	15646	69127	25630	2.70	2.07	0.6313*	0.990
CENG	Israel	2000-4	2697	9319	5418	1.72	2.49	0.7432	0.987
CENG	Israel	2005-9	2643	10338	6270	1.65	2.55	0.7559	0.994
CENG	Israel	2000-9	5340	19657	10040	1.95	2.37	0.7157	0.994
VETE	Brazil	2000-4	2155	10750	5845	1.84	2.33	0.7057*	0.991
VETE	Brazil	2005-9	4868	26522	14873	1.78	2.55	0.7559	0.992
VETE	Brazil	2000-9	7023	37281	18535	2.01	2.37	0.7157	0.991
VETE	Spain	2000-4	1384	7338	3852	1.90	2.24	0.6821*	0.987
VETE	Spain	2005-9	2543	15162	8368	1.81	2.33	0.7057*	0.991
VETE	Spain	2000-9	3927	22500	10468	2.05	2.22	0.6765*	0.992
VETE	Turkey	2000-4	1808	6077	2438	2.49	1.74	0.5064	0.993
VETE	Turkey	2005-9	3002	10964	4092	2.68	1.82	0.5391	0.972
VETE	Turkey	2000-9	4811	17041	5179	3.30	1.63	0.4528	0.978
COMP	Brazil	2000-4	3101	9981	5980	1.67	2.52	0.7497	0.986
COMP	Brazil	2005-9	10165	36374	17336	2.10	2.26	0.6875	0.996
COMP	Brazil	2000-9	13266	46355	20772	2.23	2.25	0.6848	0.990
COMP	Belgium	2000-4	3155	10996	5212	2.11	2.29	0.6955	0.993
COMP	Belgium	2005-9	8535	32349	13325	2.47	2.29	0.6955	0.984
COMP	Belgium	2000-9	11290	43345	16598	2.61	2.19	0.6680	0.989
COMP	Sweden	2000-4	3424	9734	5430	1.79	2.36	0.7132*	0.995
COMP	Sweden	2005-9	7903	27008	12994	2.07	2.21	0.6737*	0.992
COMP	Sweden	2000-9	11327	36742	16301	2.25	2.15	0.6562*	0.994
PHAR	Brazil	2000-4	3530	16882	9765	1.73	2.50	0.7454	0.996
PHAR	Brazil	2005-9	7045	40068	21038	1.90	2.35	0.7107	0.998
PHAR	Brazil	2000-9	10575	56950	26883	2.12	2.29	0.6955	0.994
PHAR	Spain	2000-4	7531	35174	16668	2.11	2.25	0.6848	0.995
PHAR	Spain	2005-9	8852	47055	23351	2.01	2.38	0.7181	0.991
PHAR	Spain	2000-9	16383	82229	33881	2.42	2.16	0.6592	0.992
PHAR	Sweden	2000-4	3648	16223	9182	1.77	2.52	0.7497	0.991
PHAR	Sweden	2005-9	4129	21236	12339	1.72	2.49	0.7432	0.996
PHAR	Sweden	2000-9	7777	37459	18766	2.00	2.41	0.7252	0.995
MATH	Greece	2000-4	2502	6283	3233	1.94	2.30	0.6981*	0.983
MATH	Greece	2005-9	5049	14864	7388	2.01	2.34	0.7083	0.980
MATH	Greece	2000-9	7551	21147	9187	2.30	2.18	0.6651	0.988
MATH	Mexico	2000-4	2236	5700	3046	1.87	2.33	0.7057	0.990

MATH	Mexico	2005-9	4187	12049	6271	1.92	2.35	0.7107	0.994
MATH	Mexico	2000-9	6423	17749	8087	2.19	2.19	0.6680*	0.985
MATH	Sweden	2000-4	2756	6485	4167	1.55	2.67	0.7774	0.988
MATH	Sweden	2005-9	5032	13806	7946	1.74	2.36	0.7132*	0.999
MATH	Sweden	2000-9	7788	20291	10888	1.86	2.30	0.6981*	0.990
ECON	Spain	2000-4	1662	3434	2145	1.60	2.45	0.7344*	0.974
ECON	Spain	2005-9	3353	7840	4755	1.65	2.40	0.7228*	0.994
ECON	Spain	2000-9	5015	11274	5952	1.89	2.25	0.6848*	0.983
ECON	Sweden	2000-4	889	1806	1159	1.56	2.48	0.7410*	0.992
ECON	Sweden	2005-9	1551	3414	2052	1.66	2.41	0.7252*	0.993
ECON	Sweden	2000-9	2440	5220	2749	1.90	2.20	0.6708*	0.984
ECON	China	2000-4	385	908	636	1.43	2.47	0.7388*	0.995
ECON	China	2005-9	2447	6283	3256	1.93	2.32	0.7032*	0.978
ECON	China	2000-9	2832	7191	3595	2.00	2.28	0.6928*	0.998
BUSI	Spain	2000-4	1070	2447	1846	1.33	3.08	0.8425*	0.994
BUSI	Spain	2005-9	3033	8096	5313	1.52	2.60	0.7660*	0.998
BUSI	Spain	2000-9	4103	10543	6539	1.61	2.47	0.7388*	0.997
BUSI	France	2000-4	1219	2599	2059	1.26	3.00	0.8319*	0.996
BUSI	France	2005-9	2791	6917	5217	1.33	2.95	0.8248*	0.997
BUSI	France	2000-9	4010	9516	6769	1.41	2.76	0.7952*	0.998
BUSI	India	2000-4	2728	5615	2931	1.92	2.39	0.7205*	0.985
BUSI	India	2005-9	3776	9465	4718	2.00	2.24	0.6821*	0.993
BUSI	India	2000-9	6504	15080	6726	2.24	2.15	0.6562*	0.997
SOCI	Brazil	2000-4	1328	3507	2959	1.18	3.54	0.8910*	0.997
SOCI	Brazil	2005-9	5588	13637	10879	1.25	3.29	0.8670	0.993
SOCI	Brazil	2000-9	6916	17144	13224	1.30	3.10	0.8450	0.996
SOCI	Belgium	2000-4	1933	4578	3243	1.40	2.78	0.7985*	0.997
SOCI	Belgium	2005-9	4475	12673	8158	1.55	2.63	0.7718*	0.997
SOCI	Belgium	2000-9	6408	17251	10347	1.67	2.50	0.7454*	0.992
SOCI	Mexico	2000-4	865	2254	1950	1.16	3.57	0.8935*	0.998
SOCI	Mexico	2005-9	2141	6472	5350	1.21	3.24	0.8615*	0.999
SOCI	Mexico	2000-9	3006	8726	6914	1.26	3.10	0.8450*	0.999
ARTS	Canada	2000-4	1939	3059	2416	1.27	3.33	0.8712	0.986
ARTS	Canada	2005-9	4032	6490	5027	1.29	2.91	0.8190*	0.995
ARTS	Canada	2000-9	5971	9549	6755	1.40	2.79	0.8002	0.995
ARTS	Spain	2000-4	1138	1952	1550	1.26	3.33	0.8712*	0.995
ARTS	Spain	2005-9	2276	4385	3601	1.28	3.18	0.8547*	0.999
ARTS	Spain	2000-9	3414	6337	4867	1.30	3.11	0.8462*	0.998
ARTS	Italy	2000-4	796	1700	1403	1.21	3.54	0.8910*	0.995
ARTS	Italy	2005-9	1852	3816	3073	1.24	3.30	0.8650*	0.995
ARTS	Italy	2000-9	2648	5516	4089	1.35	2.96	0.8263*	0.995

[a]The acronym for each subject area studied, used as a term in the Scopus database search formula.
[b]The country (one of three studied for each subject area and time period), used as a term in the search formula.
[c]Time period covered (2000-2004, 2005-2009, or 2000-2009).
[d]Number of records resulting from the particular search in the subject area, country, and time period.
[e]Sum of the number of authors for each record (apparent works).
[f]Total number of different authors.
[g]Productivity – the ratio between authorship and the number of authors.
[h]Truncated Lotka exponent (parameter) – value of the exponent after applying the cut-off to the distribution.
[i]Truncated Lotka constant (parameter), corresponding to the proportion of authors with a single published work, obtained using $n(t)$, i.e., after applying the cut-off to the distribution.
[j]The coefficient of determination, obtained after applying the cut-off to the distribution.
[*]Statistically significant according to the Kolmogorov-Smirnov goodness-of-fit test at the 0.01 significance level, meaning that the data are consistent with a Lotka distribution.

Correlations between Data Characteristics and Lotka's Law Parameters

Table 2 presents the results of the correlation analysis between *a/b*, *n*(*t*), and *c*(*t*). The correlations of *a/b* with the other two parameters were negative, and that between *c*(*t*) and *n*(*t*) was positive. All three cases were significant at the 0.01 level.

Table 2: Correlations between Productivity (a/b), Exponent (n(t)) and Fraction of Authors with One Paper Each (c(t))

		a/b	*c(t)*
n(t)	Pearson correlation	-0.885**	0.968**
	p-value (bilateral)	0.000	0.000
	N	90	90
c(t)	Pearson correlation	-0.930**	1
	p-value (bilateral)	0.000	
	N	90	90

**. The correlation was significant at the 0.01 (bilateral) level.

Comparing Three Disciplines According to their Productivity Means

Table 3 presents the results of analysis of variance (One-Way ANOVA) by comparing the three kinds of area (Science & Technology, Social Science and Arts & Humanities), with respect to the productivity means.. In the three cases, the differences were significant at the 0.01 level.

Table 3: One-way ANOVA for Areas of Science & Technology, Social Sciences and Arts & Humanities (Productivity)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.716	2	3.858	39. 95	.000
Within Groups	8.401	87	0.097		
Total	16.117	89			

DISCUSSION

Wagner-Döbler and Berg (1995) in their article "*The dependence of Lotka's law on the selection of time periods in the development of scientific areas and authors*" observed that the slope of the distribution of authors was steeper the longer the time period selected for study. They state that in subject areas which are in an expansive phase there will be major effects of the influx of new authors and this will be reflected in the form of the Lotka distribution (p. 35). In particular, they note that the Lotka distribution in less dynamic scientific areas may reflect greater concentration (lower values of the parameters *n* and *c*), and that, in sum, the Lotka distribution of many scientific disciplines depends on their state of development (p. 36). This set of ideas is what led us to carry out the present study. Our aim was to examine whether the characteristics of the Lotka distribution of publications (in particular, the changes that the two parameters, *n* and *c*, undergo) constitute an indicator of the structure of influence in a scientific field.

Influence of the Subject Area's Growth and Scientific Productivity (Dynamism)

The dynamism of a scientific area undergoing major growth was found to affect the Lotka distribution, with its two parameters, *n* and *c*, being lower in the second period (2005-2009) than in the first (2000-2004) due to the increase in productivity. A clear example of this was the subject area of Dentistry (DENT) in Brazil. The growth in publications (records), authorship, and authors from the first to the second time periods was by factors of between 3 and 4, and productivity went from 1.87 papers per author in the first period to a value of 2.25 in the second. For the Lotka distribution, the fraction of authors with only one published work declined from 0.76 in the first period to 0.67 in the second, and the exponent from 2.57 to 2.20. The behaviour is quite different, and can even be in the contrary sense, for subject areas that are growing only slowly. A clear example was Chemical Engineering (CENG) in which records, authorship, and authors grew by a factor of less than two between the first and second periods. This was accompanied by a fall in productivity in some cases, and increases in the values of the two parameters of the Lotka distribution, constant *c* and exponent *n*.

These results contradict the assertion of Wagner-Dobler and Berg (p.36) that: "*So far one thing is certain: poor dynamics of a scientific area can influence the Lotka distribution in the direction of a stronger concentration (the exponent and the constant getting smaller).*"

Influence of the Subject Area

In the analysis of the subject areas, there was a feature common to the social sciences and humanities which distinguished them from the areas of science. The social sciences and humanities had a much lower average value of co-authorship, i.e., fewer authors per paper than did the areas corresponding to the hard sciences. This behaviour was reflected in generally higher values of the Lotka's law parameters. Also, when plotted, the distributions of the four social sciences and humanities subject areas (ECON, BUSI, SOCI, and ARTS) presented a much shorter tail than the areas of science, and their levels of productivity were lower. This reduction was because their large producers had far lower levels of productivity compared with those of science. For example, for Pharmacy (PHAR) in Spain (2000-2009) the most productive author published 1004 papers, while the two most productive authors for Social Sciences (SOCI) in Mexico (2000-2009) published 12 papers each, a difference of almost two orders of magnitude.

Nevertheless, the areas of humanities and social sciences gave better fits to Lotka's law than did those of science. In other aspects, there was really no major distinction between different subject areas according to whether or not they were a science, and our results agree with Wagner-Dobler and Berg's (1995) observation (p. 36) mentioned above that the Lotka distribution of many scientific disciplines depends on their state of development.

Influence of the Country

The state of development of a subject area was also analyzed by studying it in different countries. Emerging countries such as Brazil, with a high growth rate and strong development in certain areas, have an author distribution with low values of the parameters, unlike those found for other countries in which the same subject area is in a later stage of development or is already firmly established. An example was the Pharmacy subject area in Brazil as compared with Spain and Sweden. This different behaviour of the same area in different countries suggests that the geographical zone may also influence the parameters of the Lotka distribution of a given subject area.

Influence of the Period of Time

It was also possible to appreciate the influence of the time period considered, whether between the first and second periods, or between each of them and the total period (2000-2009). It is of course logical that, with a longer time period, the authors can produce more, so that the average productivity (*a/b*) increases. Hence, with the same reasoning as before, it is also logical that with the longer time period, the values of the Lotka parameters should be lower as the productivity increases. In highly dynamic, growing subject areas in which there was a major increase in records and authors from 2000-2004 to 2005-2009, productivity generally also rose, and the values of the Lotka parameters fell. An example was Dentistry (DENT) in Brazil.

However, in more settled, well-established subject areas or in certain countries, this is not the case. Although they may have experienced growth in publications and authors, the productivity remains the same or even declines, with the consequent reflection of this behaviour being reflected in the parameter values, which either remain stable or rise in the second period. An example was the Chemical Engineering (CENG) subject area. The two equal length time periods studied (2000-2004 and 2005-2009) showed different patterns of behaviour, at least in the more dynamic subject areas. In general, the productivity was higher in the second period, with the corresponding decrease in the Lotka distribution parameters.

Vlachý (1976, p. 48) also found that: "*The value of the slope n varied according to: (a) the characteristics of the author population; (b) [as a function] of [the] time period under study.*"

CONCLUSION

The principal aim of this study was to examine the data of author productivity in a certain number of cases (a combination of subject areas, countries, and time periods), to determine whether there were characteristics that influenced the parameters of Lotka's law. The findings indicated that, in most of the cases, the two parameters of Lotka's law, the exponent *n* and the constant *c*, were influenced by the subject area's productivity and growth, by the type of area, the country, the time period, and the length of that period. As also was reported by Pao (1986), no relationship whatever was found between the values of *n* and *c* and whether or not the subject area belonged to the "*hard sciences*".

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