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ORIGINAL PAPER

AN EXAMINATION OF LOTKA'S LAW & AUTHOR'S PRODUCTIVITY IN THE FIELD OF SUPPLY CHAIN MANAGEMENT

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ABSTRACT. **Background:** The development of supply chains appeared in a structured way in the 1990s. Previous studies have not examined in detail the research productivity patterns of the distribution of individual supply chain management authors with a lengthy time frame. Previous studies have also not set standards of individual research productivity, in terms of both quantity and quality, which are necessary to be ranked among the leading contributors in the field.

Methods: To address the above mentioned issue in this field, the paper examine 458 articles written by 980 authors from 2005 through 2014. The study presents six metrics concerning quality and quantity of productivity and identifies the aggregate productivity standards necessary for individual authors to be ranked at various positions in the field of supply chain management. In the last, the paper examines the validity of Lotka's law to authorship pattern in the field of supply chain management. Lotka's law was tested using generalized form, and K-S goodness-of-fit tests were applied.

Results: This study provides a set of comprehensive, useful and recent standards for individual publication productivity in supply chain management discipline within the selected journal outlets. The findings suggests that to be in position top 10, top 20, and top 50 an author required h-index value 4, 3, and 2 respectively. This work contributes to the literature by identifying standards of individual research performance across six different metrics of quantity and/or quality. The results can inform current supply chain management scholars and administrators of productivity standards as implicitly established by the body of scholars in the SCM field.

Conclusions: The result found that the author productivity distribution data in the supply chain management field follow Lotka's law. The results of this study provide a new outlook on supply chain management research. In the last, major research areas and potential future directions were also provided.

Key words: supply chain management, benchmarking, authorship pattern, Author's productivity, K-S test, Lotka's law.

INTRODUCTION

The research played an important role in knowledge discovery of a discipline [Powers et al. 1998]. Thus examining trends and productivity patterns in academic research have been of scholarly interest because it helps in defining individual careers and institutional success within the field [Shrivastava, Kumar 2019, Kumar 2016]. This has certainly been true of supply chain management, where [Kumar, Kushwaha 2015, Kumar 2016] among many others, have helped to understand the state of development of the supply chain management field. These types of studies also provide some degree of productivity for individual authors and institutions as they show research outcome and see progress toward such goals. Publication productivity assessments provide useful information which can be useful in faculty recruitments, promotion and tenure decisions. However, the previous literature on research and publication productivity in supply chain management has been largely concentrated on a number of publications by an individual or the institute [e.g. Kumar, Kushwaha 2015]. Prior research has largely focused on quantity measures (such as a number of publications), and not as much

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on quality measures (such as the number of citations received). Thus, the previous study does not provide particular standards of productivity of an author that can necessarily be used directly by an individual researcher to assess their contributions.

The aim of the study is to address these gaps in the literature by addressing the key question: what are the appropriate standards for excellence in publication productivity in Supply chain management. The aim of this paper is to provide a set of empirical standards for establishing research productivity. In sum, we identify the particular standards of performance that are necessary to place an individual at various positions of publication productivity in supply chain management. Using a time frame of 10 years (2005-2014) of publications from supply chain management: an international journal, we investigated four general research questions, three are based on the study of [Coleman et al. 2012] for the field of supply chain management as well as in the last question testing the Lotka's law for the dataset.

1. How many articles are required for an author to be ranked among the leaders in supply chain management publication productivity to measure quantitative productivity?
2. How many citations are required for an author to be ranked among the leaders in supply chain management to measure quality productivity?
3. What level of combined quantity and quality is required to be ranked among the leaders in supply chain management publication productivity?
4. Does the dataset follow the Lotka's law?

Furthermore, to measure the productivity in a quantitative way, we use two versions of a number of publications in this study. A number of publications represent the frequency of an author's contribution to the field and are perhaps the most commonly used method of research productivity in the academic field. Similarly, we use two versions of a number of citations in this study to measure the productivity in terms of quality. Finally, as a combination of quality and quantity measure, we use h-index to present the productivity. h-index is a popular measure because it provides the broad impact of a scientist's cumulative research contributions [Hirsch 2005] and combines a number of publications and citation counts in a "balanced way" [Shrivastava, Kumar 2019]. The paper is organised as in the next section 2, an overview of previous literature; in the next section 3 research methodology; in the next section 4, an analysis with the results; in the next section 5 testing of Lotka's law; next in section 6 conclusions and in the last section 7 limitations and future research scope of this study presented.

LITERATURE REVIEW

These days it is common in most of the discipline to rank and evaluate the research productivity. Even many European countries are in the process of developing national measures of research quality and impact [Harland 2013]. An objective way of measuring productivity through no of publications of an individual or an institution and number of citations an article received used by various researchers in the different domain of research [Shrivastava, Kumar 2019, Kumar 2016, Tsai, Chi 2011].

The study conducted by Valencia [2004], in the Philippines since 1998-2002 for science and engineering departments of the two lead research universities and found that the average productivity of the faculty surveyed is less than one.

Swihart et al. [2016], conducted research on 437 tenure-track faculty members at 33 universities in the United States belonging to the National Association of University Fisheries and Wildlife Programs. For each faculty member, they computed 8 commonly used performance metrics based on numbers of publications and citations. They found that there is variation in publication and citation metrics due to academic age, sex, research appointment, and sub-disciplinary focus.

Due to the importance of research in the field of SCM, many papers published in SCM journals over the last decade related to research productivity, impact, and/or quality [Gorman,

Kanet 2011, Ellinger, Chapman 2011, Rao et al. 2013, Maloni et al. 2009, Kumar 2016, Shrivastava, Kumar 2019].

Kumar [2016] presented productivity by year of publication, study type, methodology, type of supply chain investigated, authorship pattern, country wise distribution of articles. Crum et al. [2011] do the same for the first 40 years of the International Journal of Physical Distribution and Logistics Management. Kumar and Kushwaha [2015], presented a number of publications by an individual author/ institute from 2005-14 in the supply chain management field through a single journal. Most of these studies are either based on a number of publications of an individual or number of publications of an institute in a particular discipline. In the present scenario, the focus has been shifted from the quantitative & qualitative analysis of productivity to the combined productivity of an individual to set standards for productivity measurement. However, such research is very limited in the field of supply chain management. While the aforementioned studies have made important contributions to the supply chain management discipline, there remains an opportunity for additional research that identifies individual publication productivity standards in terms of both quantity and quality. Addressing these opportunities is the rationale for the current research.

RESEARCH METHODOLOGY

The study examined the authorship of each article published in the 10-year period from 2005-2014, in the supply chain management: an international journal. Emerald was used as the source for data collection. Over the years of 2005-2014, a total number of 458 articles from supply chain management: an international journal abstract has been downloaded from the website. The required data of all the articles related to the productivity analysis, such as the title of the articles, number of authors etc. were taken from the Emerald database. Our data set includes 458 articles, a number that represents a near to 50% of all articles published so far since journal start publishing [1996] over this 10-year span. The new articles excluded from dataset intentionally because new articles do not have citations and the results may be biased. Thus to avoid this, this dataset was chosen for the study purpose.

The collection of the various author names associated with each article helped us to develop quantitative metrics for each author. For quality measurement of each contribution, we also collected the number of citations that were generated by each article as of May 2016. Authors used Google Scholar instead of the Thomson ISI Web of Science to calculate its citations because it is freely available to anyone [Bosman et al. 2006] and presents a better complete picture of an academics impact than the Thomson ISI Web of Science. The study conducted by [Meho, Yang 2007], concluded that there is no significant change in the ranking of the academics when citations are calculated using Google scholar and web of science.

The use of citations in this study helps specifically to captures each author's collective contribution to the field. While recently published papers by newer contributors to the field, by definition received lower citation counts, this lower score is arguably appropriate given the still-limited exposure of the article / author. While authors in such a position may be strong researchers, they clearly have not yet established themselves as productive authors in the field.

To answer our first research question setting standards for a number of articles an author needs to be among the leading contributors to the supply chain management field. We computed two versions of an article count for each author through direct count method and equal credit method. The direct count method assigns a value of 1.0 for each author, regardless of the number of authors. This metric gave full credit for an article to each and every author on that article and treated single authorship and joint authorship as the same, but this approach is seen as having two major drawbacks. First, researchers who tend to work independently can potentially receive lower scores than researchers who tend to work collaboratively. Second, this method negatively impacts the ranking of those who tend to co-author a large number of papers

with multiple authors while keeping their contribution to each paper marginal. This approach was used in various past studies [Kumar, Kushwaha 2015, Shrivastava, Kumar 2019, Kumar 2016].

For the measurement of the second version of quantity, we employed an equal credit method. In this method, each author receives an equal portion of the score regardless of the authorship order. This addresses the problems discussed above. A per-person score is obtained by taking the inverse of the number of authors. For instance, an author of a single work receives1 point; each author of a two-authored work obtains as a score of 0.5; three-authored, 0.333, etc. This method was employed in other previous studies [Maloni et al. 2009, Shrivastava, Kumar 2019].

To address our second research question regarding yardsticks/standards value for the publication quality threshold necessary to be among the leading contributors to the supply chain management field. Again, we computed two versions of a citation count for each author. One represented the total number of citations received for all articles on which that individual appeared as an author, i.e. direct count method. Like our first quantity measure, this metric gave full credit for all of an article's citations to each and every one of its authors, regardless of the number of authors. The second version of quality metric developed by equal credit method, where the citation credit assigned to each author on a given article was computed as the number of citations for that article, divided by the number of authors. For examples, on a two-author article with 100 citations, each author would be assigned credit for 50 citations, whereas each author on a three-author article with 100 citations would receive credit for 33.33 citations.

Now how the answer for research question third can be obtained by identifying the combination of quantity and quality necessary to be among the leaders in supply chain management research. The literature provides an option for combining quantity metrics (as measured by a number of publications) and quality metrics (as measured by citation counts): the Hirsch index, or h-index. This index was first used by Hirsch in 2005. According to Hirsch [2005] "A scientist has index h if h of his or her Np papers have at least h citations each and the other (Np - h) papers have <h citations each", where Np = number of papers. Thus, to address our third research question, we computed two versions of the h-index of each author in our sample, First one, by direct count method and another through equal credit method.

Once the raw values of each metric were computed for each author, we prepared frequency tables based on each of the six metrics (two quantity, two quality, and two combined), and arranged each frequency table from the highest value of the metric to the lowest and assign the rank. This approach gives us six separate publication productivity rankings tables. For each table, we also computed the percentile associated with each value of the metric; i.e., the percentage of all authors in the data with totals below that threshold. The resulting tables thus allow any author to easily compare his/her own totals to the entire distribution of authors that have published in this journal from 2005-2014, and to determine where they would have ranked as well as what percentage of the authors in the discipline they would have surpassed. We examine the tables to identify the minimum value necessary to lead the discipline, and to rank at various positions in the field according to each metric (e.g., the top 10, top 20, top 50, etc.).

Lokta's law

In the last Lotka's law was tested to see that our dataset follows it or not. Lotka's law is used to measure the author productivity in the given field. Lotka's basic proposition was that about 60 percent of authors who contribute to a given field make only one contribution to that field, and the pattern of contributions of more productive authors can be described by the equation

$$f(x) = C/x^n$$

where x is the number of papers published in a period; f (x) is the number of authors publishing x papers; n is a parameter to be determined from the data that taking a value close to two, and C is a normalizing constant

that the sum over all x of the f (x) is equal to one.

RESULT ANALYSIS

Among the 458 articles collected, a total of 980 different individuals contributed at least one paper, indicating an average of 2.14 authors on each article, and an average of .47 articles for each author.

Table 1 contains the ranking table for a total number of articles based on the direct count method, and Table 2 contains the ranking table for a total number of articles based on equal credit method. It would be worth mentioning here that the ranks are shown in these, and the subsequent tables reflect the impact of ties in the particular metrics. (For example, in Table 1 the ranking jumps from 3 directly to 7 at one point. This implies that three authors were tied for the 10th position).

Table 1. Ranking based on the number of publications through the direct count

Rank	No of papers	Percentile
1	9	99.9
2	8	99.8
3	6	99.69
7	5	99.39
9	4	99.18
18	3	98.26
31	2	96.94
126	1	87.24

From the Table 1, it is clear that the highest number of articles published during our study time period 9, with only two authors have published more than 6 articles. Further analysis of the number of articles depicts that the necessary minimum value for the top 10, top 20, and top 30 were 4, 3, and 2 articles, respectively.

Table 2. Ranking based on the number of publications through equal credit method

Rank	No of papers	Percentile	Rank	No of papers	Percentile
1	4.5	99.9	32	1.06	96.74
2	4.33	99.8	33	1	96.64
3	3.52	99.69	96	0.92	90.2
4	3.5	99.59	98	0.83	0.9
5	2.41	99.49	115	0.78	88.27
6	2.33	99.39	116	0.75	88.17
8	2.25	99.18	124	0.7	87.34
9	2.16	99.08	125	0.67	87.24
10	2	98.98	144	0.6	85.31
12	1.83	98.76	145	0.58	85.21
13	1.75	98.66	155	0.57	84.18
14	1.72	98.56	156	0.53	84.08
15	1.56	98.46	162	0.5	83.47
16	1.53	98.36	407	0.45	58.47
17	1.5	98.26	412	0.4	57.96
24	1.41	97.55	413	0.33	57.86
25	1.33	97.45	722	0.3	26.33
27	1.2	97.25	730	0.25	25.51
28	1.16	97.15	913	0.2	6.84
30	1.08	96.94	959	0.16	2.14

From the table 2 which is based on equal credit method, it is clear that for necessary minimum value for the top 10, top 20 and top 30 were 2, 1.5 and 1.08 articles respectively. So to be in the top 50 an author needs at least 1 publication while a total of .83 articles would have placed an author in the top 100.

Table 3 is showing the rank-ordered citation frequencies through the direct count method. From the table 3 it is clear that top rank holders are having 1027 citations while the second rank holder is quite back and having 602 citations. Furthermore, the table indicates that to be in the top 10, top 20, top 50 and top 100, an author need to be 380, 290, 214 and 166 citations respectively. From the table it is also clear that about 81% of authors have less than 100 citations. .20 % of the authors have to be cited yet so it means 99.8 % of the authors have been cited. It signifies that the authors included in the dataset are doing good quality research in the field of supply chain management.

Table 3. Ranking based on citations through direct count method

Rank	Citations direct count method	Percentile	Rank	Citations direct count method	Percentile	Rank	Citations direct count method	Percentile
1	1027	99.9	115	154	88.28	337	63	65.61
2	602	99.8	116	151	88.18	340	61	65.31
5	537	99.48	117	148	88.08	346	60	64.69
6	466	99.38	118	146	87.96	349	58	64.39
7	422	99.28	120	145	87.76	355	57	63.78
8	417	99.18	121	144	87.66	358	56	63.48
9	380	99.08	123	137	87.56	363	55	62.96
11	355	98.88	125	136	87.36	365	54	62.76
14	349	98.57	127	133	87.16	366	53	62.66
16	318	98.37	130	132	86.73	372	52	62.04
17	316	98.27	133	130	86.43	379	51	61.33
18	306	98.17	134	128	86.33	380	50	61.23
19	290	98.07	135	126	86.23	386	49	60.61
21	281	97.86	137	125	86.03	391	48	60.11
22	277	97.76	139	124	85.82	397	47	59.49
23	275	97.66	140	122	85.72	405	46	58.67
25	266	97.46	142	121	85.52	410	45	58.16
26	259	97.36	144	117	85.32	422	44	56.94
29	249	97.06	145	116	85.22	427	43	56.44
30	248	96.94	149	115	84.79	439	42	55.2
31	244	96.84	151	114	84.59	442	41	54.89
33	243	96.64	155	110	84.19	454	40	53.67
37	241	96.22	158	108	83.88	460	39	53.06
38	240	96.12	166	107	83.06	473	38	51.73
39	238	96.02	168	106	82.86	482	37	50.82
40	225	95.92	170	104	82.66	496	36	49.39
41	224	95.82	171	103	82.56	508	35	48.16
43	221	95.62	179	102	81.73	513	34	47.65
45	220	95.42	182	101	81.43	524	33	46.53
46	219	95.32	183	100	81.33	535	32	45.41
48	214	95.12	185	98	81.12	548	31	44.08
52	213	94.69	189	97	80.71	560	30	42.86
53	212	94.59	193	96	80.31	570	29	41.84
55	211	94.39	198	95	79.79	581	28	40.71
56	207	94.29	200	94	79.59	591	27	39.69
57	201	94.19	204	93	79.18	604	26	38.37
60	199	93.88	207	92	78.88	614	25	37.35
63	197	93.58	208	91	78.78	616	24	37.15
64	195	93.48	210	89	78.58	643	23	34.39
67	193	93.18	215	88	78.06	650	22	33.67
68	192	93.08	218	87	77.76	664	21	32.24
69	187	92.96	224	86	77.14	683	20	30.3
71	179	92.76	228	83	76.73	705	19	28.06
72	178	92.66	233	82	76.22	722	18	26.32
73	177	92.56	241	81	75.41	728	17	25.71
74	176	92.46	246	80	74.89	739	16	24.59
78	174	92.06	253	79	74.18	756	15	22.85
79	173	91.94	257	77	73.78	768	14	21.63
80	172	91.84	264	76	73.06	791	13	19.28
81	171	91.74	274	75	72.04	813	12	17.04
85	170	91.34	279	74	71.53	826	11	15.71
89	168	90.92	286	73	70.82	843	10	13.98
92	167	90.62	295	72	69.89	860	9	12.24
98	166	90	305	71	68.88	873	8	10.92
101	165	89.69	310	70	68.37	890	7	9.18
103	163	89.49	313	69	68.07	899	6	8.27
105	161	89.29	322	68	67.14	922	5	5.92
107	160	89.09	327	67	66.63	936	4	4.49
109	158	88.88	328	66	66.53	954	3	2.65
110	157	88.78	331	65	66.23	957	2	2.35
112	155	88.58	332	64	66.13	962	1	1.8
						979	0	0.1

Table 4. Ranking based on citation through equal credit count

Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile
1	780.5	99.9	155	44	84.19	429	17	56.23
2	330.66	99.8	162	43.5	83.47	435	16.5	55.61
3	266	99.69	163	42.75	83.37	440	16	55.11
4	249	99.59	166	42.5	83.07	446	15.83	54.49
5	243	99.49	170	42.39	82.65	447	15.66	54.39
6	240	99.39	171	42	82.55	448	15.5	54.29
7	232	99.29	172	41.75	82.45	450	15.33	54.09
8	224.58	99.19	175	41	82.15	452	15	53.88
9	217	99.09	177	40.66	81.94	462	14.5	52.86
10	193.06	98.97	179	40.5	81.74	467	14	52.36
11	183.5	98.87	184	40.25	81.24	472	13.8	51.84
12	178	98.77	185	40	81.14	476	13.66	51.44
13	174.5	98.67	187	38.99	80.92	486	13.5	50.41
15	168.13	98.47	188	38.66	80.82	488	13.16	50.21
18	168	98.16	191	38.5	80.52	489	13	50.11
19	159	98.06	194	38	80.22	492	12.7	49.79
20	156.33	97.96	196	37.5	80.02	493	12.66	49.69
21	155	97.86	198	37	79.79	497	12.5	49.29
22	153	97.76	200	36.66	79.59	501	12.33	48.88
23	147.5	97.66	203	36.33	79.29	504	12	48.58
24	141.5	97.56	204	36	79.19	517	11.75	47.24
25	138.5	97.46	211	35.32	78.47	521	11.66	46.84
26	126	97.36	213	35	78.27	522	11.5	46.74
28	118.33	97.16	215	34.5	78.07	523	11.33	46.64
31	112.8	96.84	218	34.33	77.75	527	11.25	46.24
32	112	96.74	223	34.23	77.25	529	11.2	46.04
34	110.5	96.54	224	34	77.15	530	11	45.92
36	108	96.34	231	33.5	76.43	537	10.75	45.2
37	106	96.24	232	32.66	76.33	545	10.66	44.39
39	100	96.04	234	32.33	76.13	550	10.5	43.88
40	99.83	95.92	237	32	75.82	556	10	43.27
41	98.5	95.82	242	31.49	75.32	560	9.8	42.86
42	98.33	95.72	243	31.33	75.22	564	9.66	42.46
43	97.66	95.62	246	31.25	74.89	569	9.5	41.94
44	96.66	95.52	247	31	74.79	585	9.33	40.31
46	95	95.32	250	30.5	74.49	591	9.25	39.69
47	93	95.22	251	30.33	74.39	599	9	38.88
48	91.66	95.12	253	29.83	74.19	613	8.66	37.45
50	88	94.89	254	29.33	74.09	620	8.5	36.73
51	86.33	94.79	256	29	73.88	629	8.33	35.82
54	85.5	94.49	258	28.75	73.68	631	8	35.62
56	84	94.29	261	28.5	73.38	642	7.91	34.49
57	81.5	94.19	264	28	73.08	647	7.66	33.97
60	81	93.88	265	27.5	72.96	652	7.5	33.47
63	80	93.58	267	27.33	72.76	662	7.33	32.45
64	79.16	93.48	271	27.16	72.36	670	7.2	31.63
65	79	93.38	272	27	72.26	671	7	31.53
66	76	93.28	273	26.66	72.16	676	6.75	31.03
67	74	93.18	274	26.5	72.06	680	6.66	30.61
69	73.33	92.96	275	26.33	71.94	694	6.5	29.18
70	73	92.86	281	26.32	71.34	710	6.33	27.55
74	72.5	92.46	282	26	71.24	715	6.08	27.04
75	72	92.36	286	25.76	70.82	717	6	26.84
79	70.99	91.94	287	25.75	70.72	729	5.66	25.61
80	70.25	91.84	290	25.66	70.42	731	5.5	25.41
81	70	91.74	293	25.33	70.12	740	5.4	24.49
82	69	91.64	302	25.32	69.18	744	5.33	24.08
83	68.5	91.54	304	25	68.98	750	5.25	23.47
85	68	91.34	305	24.5	68.88	759	5	22.55
86	67.83	91.24	307	24.33	68.68	776	4.75	20.82
87	67.33	91.14	314	24	67.96	777	4.66	20.72
88	66.5	91.04	318	23.75	67.56	780	4.6	20.42
90	65.16	90.82	319	23.5	67.46	781	4.5	20.32
91	65	90.72	322	23.33	67.14	790	4.43	19.39
96	63	90.22	323	23	67.04	797	4.33	18.67

Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile	Rank	citation through Equal credit method	Percentile
98	62.5	90.02	328	22.83	66.53	802	4.2	18.16
100	62.41	89.79	329	22.25	66.43	805	4	17.86
103	62	89.49	333	22	66.02	830	3.66	15.31
104	61	89.39	338	21.75	65.51	835	3.5	14.79
105	60.5	89.29	342	21.66	65.1	841	3.4	14.18
107	59.66	89.09	343	21.5	65	842	3.33	14.08
108	59.5	88.98	351	21.4	64.18	850	3.25	13.27
109	58.75	88.88	352	21.33	64.08	855	3	12.76
110	57	88.78	357	21.16	63.57	865	2.8	11.73
111	55.66	88.68	358	21	63.47	870	2.75	11.23
113	55.58	88.48	361	20.91	63.17	872	2.66	11.04
114	55.33	88.38	362	20.75	63.07	875	2.5	10.71
117	54	88.08	363	20.57	62.96	879	2.33	10.31
122	53.5	87.55	364	20.5	62.86	891	2.2	9.08
128	53	86.94	371	20.33	62.16	896	2	8.57
130	52	86.74	375	20.25	61.73	906	1.75	7.55
131	51.75	86.64	377	20	61.53	908	1.66	7.35
132	51.66	86.54	384	19.5	60.82	920	1.6	6.12
136	51	86.14	390	19.33	62.22	925	1.5	5.61
137	50.25	86.04	392	19.25	62.02	931	1.33	5
140	49	85.71	393	18.66	59.89	934	1.2	4.69
142	48.8	85.51	397	18.5	59.49	943	1	3.78
146	48	85.11	405	18.25	58.67	957	0.66	2.35
148	46.5	84.89	408	18	58.37	962	0.5	1.84
149	46.33	84.79	417	17.75	57.45	964	0.33	1.63
150	45	84.69	421	17.66	57.05	970	0.25	1.02
152	44.72	84.49	424	17.5	56.73	973	0.16	0.71
153	44.5	84.39	426	17.33	56.53	979	0	0.1

Table 4 is showing the ranking based on citations through equal credit method. It is clear from the table that to be at first place an author needs 780.5 citations while for the second position 330.66 citations needed. To be in the top 50, top 100, and top 200 an author needs 88 citations, 62.41 citations and 36.66 citations respectively. Moreover it is also clear from the table that more than 85 % of authors are having less than 50 citations so only 15% of authors are having above 50 citations. It is also clear that about 2.5% of authors have less than 1 citation. Two papers yet to be cited.

Table 5 is showing the h-index value through direct count method. This table is showing that to be in position first an author must have h-index 9. To be in position top 10, top 20, top 50, and top 100 an author required h-index value 4, 3, 2 and 2 respectively. It is also clear from the table that more than 87% of authors are having either 1 or less than 1, h-index value. Thus only 13 % of the authors are having above 1, citations from the dataset.

Table 5. Ranking based on h-index through the direct count

Rank	h – index	Percentile
1	9	99.89
2	7	99.79
3	6	99.69
7	5	99.28
9	4	99.08
18	3	98.16
31	2	96.83
125	1	87.24

Table 6. Ranking based on h-index through equal credit count

Rank	h-index through equal credit method	Percentile
1	7	99.89
2	5	99.79
5	4	99.48
14	3	98.57
29	2	97.04
114	1	88.37
175	0	82.14

The table 6 is showing h-index values based on equal credit method. From the table it is clear that the h-index values for the top 10, top 20 and top 30 are 3, 3 and 2 respectively. It is also clear from the table that about 18% of authors are having h-index value at-least 1. It means they have at least one paper having

citation one or more than one. Thus the work of the rest of the authors remains unrecognised yet.

Lotka's law

Authors extended the analysis on research productivity by exploring the overall productivity distribution patterns of all authors being active in the field of supply chain management. This helps not only to understand the structure of this field, but also enables comparison with other fields and an estimation of future research productivity. For this, prior productivity studies tested the application of Lotka's law [Serenko, Bontis 2004], which describes a frequency distribution of scientific productivity in a certain field of research. It is also called "the inverse square law of scientific productivity" [Lotka,1926]. Lotka [1926] found the publication data and formulated it to predict an approximate number of authors with a certain frequency of publications. Lotka's distribution function is given by the expression:

$$f(x) = C/x^n \qquad (2)$$

where x is the number of papers published in a period; f (x) is the number of authors publishing x papers; n is a parameter to be determined from the data that taking a value close to two; and C is a normalizing constant that the sum over all x of the f (x) is equal to one.

The least-squares method described by [Pao 1985] was employed for this study and he suggested these steps to verify the reliability of Lotka's Law: (1) collecting data, (2) list author frequency distribution table, (3) calculating n value (slope), (4) calculating constant C value, and (5) using K-S (Kolmogorov-Smirnov) test to evaluate whether to matched Lotka's Law.

Table 7. Productivity Analysis of Authors

No of papers (x)	Author(y)	Observed % of Authors	X = Log x	Y=Log y	XY	XX
1	855	87.24	0	2.93	0	0
2	95	9.7	0.301	1.98	0.596	0.0906
3	13	1.33	0.477	1.11	0.529	0.2275
4	9	0.92	0.602	0.9542	0.574	0.3624
5	2	0.2	0.699	0.301	0.21	0.489
6	4	0.41	0.778	0.602	0.468	0.605
8	1	0.1	0.90308	0	0	0.815
9	1	0.1	0.95424	0	0	0.91
Total	980	100	4.71432	7.8772	2.377	3.4995

In this stage, the n value was calculated by Lotka's method using the following equation:

$$n = \frac{N \sum XY - \sum X \sum Y}{N\sum X^2 - (\sum X)^2}$$

Applying the values from above table into above equation, we can get the value of n = -3.14.

In the fourth stage, the value of constant C was calculated using the following equation:

$$C = \frac{1}{\sum_1^{p-1} 1/x^n + 1/(n-1)P^{n-1} + 1/2P^n + n/24(P-1)^{n+1}}$$

Putting the value of n, x & P we get the value of C which is 0.8474576. According to Pao [1985], the absolute value of n should be from 1.2 to 3.8 which was formulated by the generalized Lotka's law. In order to test whether our observed value match with the theoretical value, we further used the K-S test for evaluation. The K-S critical value at 5% level of significance is calculated as $1.36/\sqrt{\sum y}$, where $\sum y$ is the total number of authors under study. If the absolute maximum difference (Dmax) is less than the K-S critical value, then the null hypothesis is accepted that the observed and theoretical distributions are the same. K-S test at 5% significance level was used to obtain "best fit" for the dataset. Finally, according to the K-S test, below Table

8 found Dmax= 0.025. (Dmax= Absolute Value | Fo(X) / Sn(X)) |). The critical value is equal to .052. Since the value of Dmax is less than the critical value, the result matched the generalized Lotka's law, that is, the author productivity distribution data is consistent with supply chain management studies.

Table 8. Authors' productivity Analysis

No of papers (x)	No of Authors(y)	Observed value	Accumulated Value Sn(X)	Expected Value by Author(s) %	Accumulated Value Fo(X)	Absolute Value Dmax= |Fo (X)-Sn(X)|
1	855	0.8725	0.8725	0.8475	0.8475	0.025
2	95	0.0969	0.9694	0.0961	0.9436	0.0258
3	13	0.0134	0.9827	0.0269	0.9705	0.0122
4	9	0.0092	0.9919	0.0109	0.9814	0.0105
5	2	0.002	0.9939	0.0054	0.9868	0.0071
6	4	0.004	0.9979	0.0031	0.9899	0.009
8	1	0.001	0.9989	0.0012	0.9911	0.0079
9	1	0.001	0.9999	0.0008	0.9919	0.008

The reason for the higher value of n in the area of supply chain management is that approximately 87.24% of contributors have published only one publication, whereas Lotka assumed that approximately 60% of contributors have a single publication [Coile 1977].

CONCLUSIONS

This study provides a set of comprehensive, useful and recent standards for individual publication productivity in supply chain management discipline within the selected journal outlets. Past bibliometric supply chain management research has primarily focused on ranking academic journals and academic institutions. Our work contributes to the literature by identifying standards of individual research performance across six different metrics of quantity and/or quality. The results can inform current supply chain management scholars and administrators of productivity standards as implicitly established by the body of scholars in the discipline through the selected journal.

LIMITATION AND FUTURE RESEARCH SCOPE

The biggest limitation of this work is that we have taken only a single journal thus results cannot be generalised. Assessing how individual publication productivity develops in the future represents an excellent area for further research. The establishment of productivity standards also provides an opportunity to see whether there are specific demographic or research environment factors that are related to whether an author meets or exceeds these standards. Furthermore researchers can also investigate cross-institutional collaboration effects and success factors for research productivity as further research in the field of supply chain management.

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ANALIZA PRAWA LOTKI ORAZ PRODUKTYWNOŚCI AUTORÓW W OBSZARZE ZARZĄDZANIA ŁAŃCUCHEM DOSTAW

STRESZCZENIE. **Wstęp:** Rozwój łańcuchów dostaw w formie ustrukturyzowanej pojawił się w latach 90-tych. Wcześniejsze badania nie analizowały szczegółowo wzorów produktywności dystrybucji poszczególnych autorów tematyki zarządzania łańcuchem dostaw w dłuższym okresie czasu. Nie określały również standardów badania produktywności, zarówno pod względem jakościowych jaki i ilościowych, co jest niezbędne w procesie wyłowienia liderów w tym obszarze.
Metody: W celu realizacji proponowanej tematyki, analizie poddano 458 prac napisanych prze 980 autorów w okresie 2005 do 2014. W pracy użyto sześciu miar określających produktywność zarówno pod względem jakościowym jak i ilościowym, identyfikujących standardy zagregowanej produktywności dla poszczególnych autorów, umiejscowionych w różnych obszarach tematycznych odnośnie zarządzania łańcuchem dostaw. Następnie poddano analizie wiarygodność prawa Lotki odnośnie wzorów autorstwa w obszarze zarządzania łańcuchem dostaw. Prawo to było testowane przy pomocy standardowej formy jak i testów K-S.
Wyniki: Wyniki pracy umożliwiają stworzenie użytecznych i kompleksowych standardów dla produktywności poszczególnych publikacji w obszarze tematyki zarządzania łańcuchem dostaw dla wybranych czasopism. Zgodnie z wynikami, aby autor był umieszczony odpowiednio na pozycjach: pierwszych 10-ciu, 20-stu i 50-ciu musimy uzyskać h-index odpowiednio 4, 3 oraz 2. Zidentyfikowano standardy analizy przy użyciu sześciu różnych miar zarówno ilościowych jak i jakościowych. Wyniki badań mogą być wsparciem w pracy naukowców oraz administratorów w zakresie standardów produktywności w obszarze zarządzania łańcuchem dostaw.
Wnioski: Na podstawie otrzymanych wyników stwierdzono, że rozkład produktywności autorów w obszarze zarządzania łańcuchem dostaw podlega prawu Lotki. Otrzymane wyniki umożliwiają nowe spojrzenie na badania w obszarze zarządzania łańcuchem dostaw. Dostarczają również informacji o potencjalnych kierunkach badań w przyszłości.

Słowa kluczowe: zarządzanie łancuchem dostaw, benchmarking, patent autorski, produktywność autora, test K-S, prawo Lotki

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