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Relative bibliometrics of intellectual capital and knowledge management in SCOPUS

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Abstract

The purpose of this work is a bibliometric analysis of the evolution of knowledge management (KM) and intellectual capital (IC) as scientific fields in time. The used data was all articles having "intellectual capital" or "knowledge management" in their title from SCOPUS database exported in Excel and R language is used to compute the indexes. The analysis is using the indexes (H index, N index, G index, I index, lotka's law), which are most related to references and citations of the articles. We find that KM and IC fields are heterogeneous in cases and homogeneous in other cases vis à vis the applied indexes. This analysis is usefull to researchers in the two areas to find the pionners and the most productive authors to potentially collaborate with them and, the most read articles to use them in literature review. In databases of researches, only H index is offered but to all articles of area defined by the database and not for a set of requested articles. This paper is filling this gap, as the first study of KM and IC using relative bibliometric indexes.

Keywords: Relative bibliometric indexes; H index; N index; G index; I index; Lotka's law; intellectual capital; knowledge management.

1. Introduction

The beginning of scientific research is to conduct a methodical study in order to prove a hypothesis or to answer a specific question. Finding a definitive answer is the central goal of any experimental approach. One can also say that it is a dynamic process or a rational approach that allows us to examine phenomena, problems to be solved, and to obtain precise answers from investigation.

Intellectual capital is a non-monetary element with no physical substance, constituted by information and knowledge held, and having a positive value, by an organization

Three types of IC can be distinguished:

- Automated information (software and databases),
- Property rights to innovations (patents, copyrights, trademarks, etc.)
- Economic skills (human capital, organizational know-how...

We call KM software methods and tools to identify and capitalize knowledge in order to organize and disseminate knowledge. Knowledge can be individual (attached to a person) or collective (shared by a group of people). They may be based on studies (training) or practice (experience or tacit know-how). In all cases, they are based on the individuals who make up the company.

Bibliometrics are the application of mathematical and statistical methods to books, articles and other averages of communication (Ingwersen et al., 2007). It is based on classifications, pre-established schedules, and consists in counting the number of publications (articles or patents) having a particular characteristic, belonging to such a category of classification. It also measures the productivity of an author, country, institution, and the impact of a journal, a theme, an author (using counts references that received some work for a period).

Section 2 presents related works in bibliometrics. Section 3 is devoted to illustrate used data and relative bibliometric Indexes. Section 4 is an application of bibliometric Indexes to IC and KM. Section 5 is a comparison of IC and KM using relative bibliometric Indexes. We conclude our work in section 6.

2. Related works

The bibliometric researches count thousands of articles, we chose some of them to clarify our context. Smolinsky (Smolinsky, 2016) observed a theoretical bias that raises the expected number of citations for low citation fields and reduces the expected number of citations for high citation fields where interdisciplinary publications are included in the examination of the theoretical base of the normalization method particularly determining the expected number of citations. Thelwall and South (Thelwall and South, 2016) presented a more refined method to identify differences: the geometric average normalized citation score based on comparisons between disciplines, the years and the country of two million articles journals to demonstrate the importance of collaboration in research, as is the fact that articles with other authors tend to be cited. Nevertheless, although previous studies have investigated whether the apparent advantage of collaboration varies by country, discipline, and the number of co-authors. Masoud et al. [Masoud et al., 2016) proposed a new SimCC method (similarity based on the content and citations) that addresses aspects, content and citations, to calculate similar scientific articles. Currently, the trend is to mix content analyses and bibliometric analyses in a same analysis and systematically. Serenko et al (Serenko et al, 2010), during the period under investigation (1994-2008) on articles of IC and KM, found that 2,175 articles were published by 3,109. It was found that each article was written by 1.94 authors. Therefore, there has been a decline in single-authored works over time.

Biljeck (Biljeck, 2016) analysed a set of 12,436 papers published in 20 GIScience journals in the period 2000–2014 and found that 5% countries account for 76% of global GIScience output; a paper published 15 years ago received a median of 12 citations; and the share of international collaborations in GIScience has more than tripled since 2000 (31% papers had authors from multiple countries in 2014, an increase from 10% in 2000). Bolivar et al (Bolivar, 2014) found that collaborations between researchers from different areas is favored, resulting in the publication of many articles in journals with international impact.

3. Used data and relative bibliometric indexes

Tab. 1 describes the relative indexes used in this work, the almost of them are related to citations.

Table 1. Most used indexes of references and citations

Indexes	Description and/or formula
H index	is the number of articles N which have been cited at least N times.
G index	is the rank g of the article accumulating at least g^2 of citations.
N index	It is calculated by dividing the H index by the number of years since first publication
Immediacy index I	Number of citations of articles published in year N/ number of articles published in the journal in year N.
i10 index	Number of articles with at least 10 citations.
Lotka's law	It argues that the number of authors publishing i articles is inversely proportional to the square of the number of articles published. So this number is equal to: $Ni=n1/i^2$, i=1,2,3,…,imax, where n1 is the number of authors who wrote an article and imax is the maximum number of articles written by an author.

H index is a valid indicator for research performance at the micro and meso levels (Bomann and Daniel, 2007). G-index is more sensitive than h-index in the assessment of selective scientists, since this type of scientist shows in average a higher g-index/h-index ratio and a better position in g-index rankings than in the h-index ones. Current research suggests that these indexes do not substitute each other but that they are complementary (Costa and Bordons, 2008). Ingwersen et al (Ingwersen et al., 2007) applied immediacy index at national level to find how immediate impact of a research in a country is. Lotka's law was tested empirically against the theoretic formula, it relates to author productivity. The remaining indexes are calculated numbers related to citations or impact of research.

The studied sample is a set of scientific articles of **1504** with "**intellectual capital**" in their titles for IC and a sample of **1998** articles with '**knowledge management**" in their titles for KM, existing in the database SCOPUS until April 15th 2016. We used the R language programs for various calculations related to bibliometric indexes having as inputs files (.csv) exported from SCOPUS.

4. Application of relative bibliometric indexes to IC and KM

We call relative indexes the bibliometric indexes usually used in bibliometric science, but this time applied to a set of articles extracted from databases or research. They may be different to the same indexes but applied to all scientific literature. We proposed this relativity because we need to reason to chosen set of articles.

4.1 Application of the index "Number of references per year" to IC and KM

Tab. 2 shows the index "Number of references per year" in the area of IC to quantify previous research in relation to article depending on the year. The reference basis for the calculation of citations per article, by author or by subject. They position the work of the article relatively to the works of references. The average of number of references is 44,10, which is relatively high.

Table 2. Index «Number of references per year » in IC.

Year	Nber of references	Nber of articles	Nber ref/article
2016	2242	43	52,13
2015	9601	138	69,57
2014	9682	154	62,87
2013	11434	185	61,80
2012	8282	151	54,84
…	…	….	…
1995	3	1	3
Average	**Total of references**	**Total of articles**	**Average/article/year**
44,074	**66332**	**1504**	**44,10**

Fig. 1 shows the index "Number of references per year" to area of IC, there is a large number of references in this area, in the early 1999 low number of references until 2002 and then progressively rapid increase since 2003 until 2013. From 2013, there was a large decrease in the number of references.

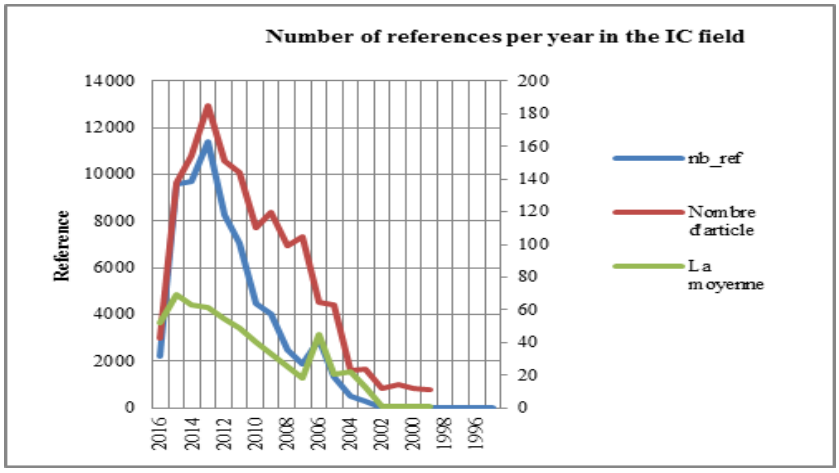

Figure 1. Number of references per year in the field of IC

Tab. 3 presents the number of references per year for the KM field.

Table 3. The index "Number of references per year" in KM.

Year	Nber of references	Nber of articles	Nber ref/article
2016	676	27	25
2015	4558	125	36
2014	7149	137	52
2013	10337	180	57
2012	7365	164	44
…	…	…	…
2000	1248	69	13
Aggregate on years	**Total references**	**Total Articles**	**Nber ref/article**
	67166	**1998**	**33,61**

The average of references per article in KM is relatively acceptable.

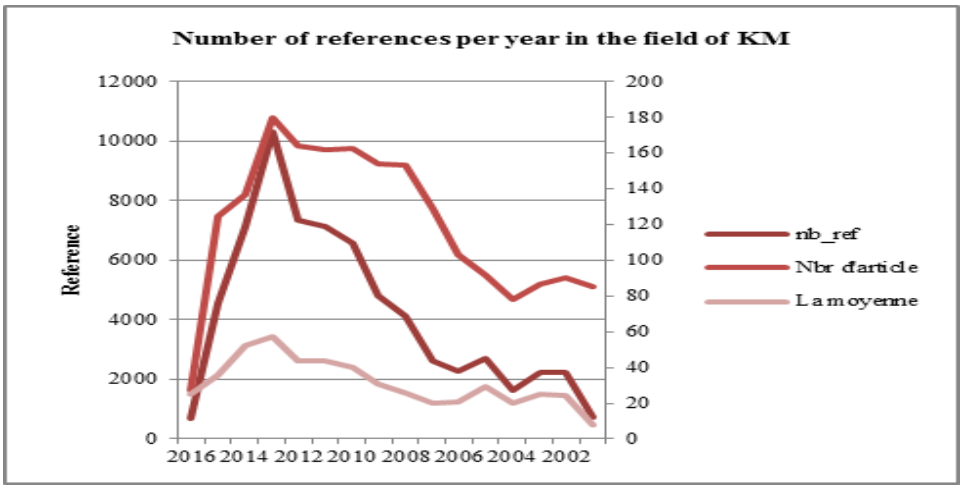

Figure 2. The index 'Number of references per year "in the field of KM

Fig. 2 shows that 2013 is the most productive year in KM, in terms of articles and references. It is the same most productive year in KM. It is not coincidence, but beacause the two areas are two faces of the same thing. Knowledge management is the process of collecting, treating, sharing knowledge and the intellectual capital is creating value from knowledge.

4.2 Application of the index "number of citations per year" to IC and KM

Tab. 4 shows citations in IC field, total and per aticle.

Table 4. Number of citations per year in IC

Year	Nber of citations	Nber of articles	Nber cit/article
1997	1239	11	112
1998	5233	12	436
…	…	…	…
2014	235	154	1
2015	61	138	0
2016	1	43	0
Aggregate on years	**Total of citations**	**Total of articles**	**Nber cit/article**
	20937	**1504**	**13,2**

The average of citations in IC is 13,92 and is relatively low. The most cited articles were in 1998.

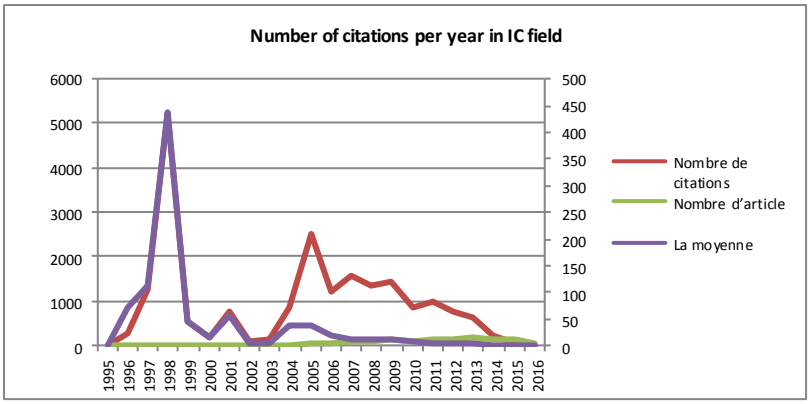

Figure 3. The index 'Number of citations per year" in IC

There has been a rapid increase in the index in the period "1985: 2000", in 1998 we reached the top and citations from 1998 a rapid and substantial recession until 2000. The period 2000-2004 knew a change in the number of citations to the 2005 peak and then repeated decrease in time until 2016.

Tab. 5 shows citations in KM field, total and per article.

Table 5. number of citations per year in KM

Year	Nber of citations	Nber of articles	Nber citation/article
2000	1581	69	25
2001	9097	85	36
2002	2689	90	52
…	…	…	…
2013	481	180	25
2014	274	137	24
2015	33	125	8
2016	3	27	18
Aggregate on years	**Total citations**	**Total Articles**	**Average**
	30560	**1998**	**15,29**

The average of citations in KM is 15,29 and is relatively high. The most cited articles were in 2001.

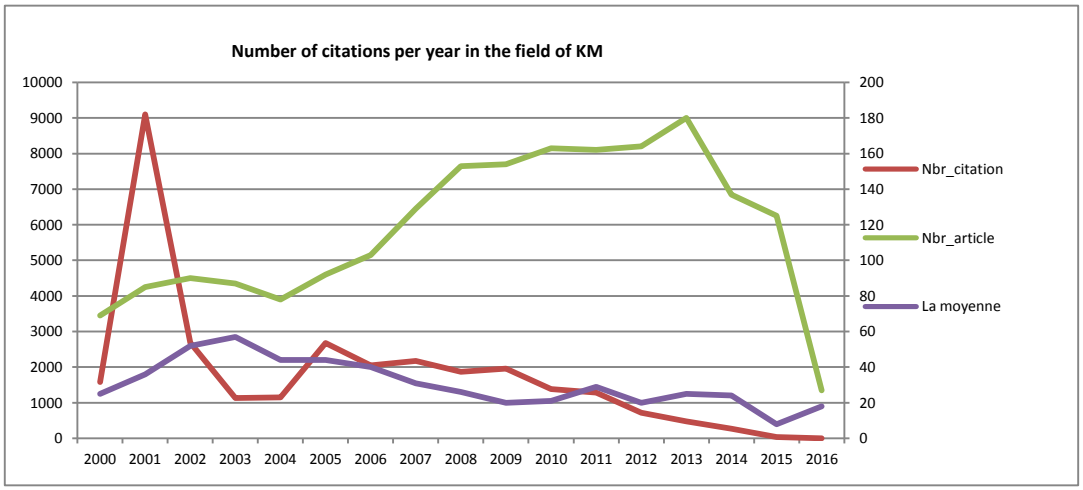

Figure 4. The index 'Number of citations per year' in KM.

Fig. 4 shows the results of the index "number of citations per year" in the field of KM. There has been a rapid increase in the years 2000 until the highest number of citations in 2001. From 2001 until 2016, there has been a rapid and substantial recession of citations.

4.3 Index "number of citations per author" in IC and KM

The number of citations per author will establish the impact of an author or article in a field or a set of requested article.

Table 6. Top ten authors relatively to the number of citations in IC and KM

Author IC	Articles	Citations	Author KM	Article	Citations
Bontis N.	33	1234	Wong K .Y.	22	659
Mouritsen J.	12	758	Anumba C.J.	19	298
Edvinsson L.	13	743	Edwards J.S.	40	242
Guthrie J.	13	538	Akhavan P.	20	191
Dumay J.	19	387	Gottschalk P.	27	159
Abeysekera I.	12	315	Jennex M.E.	51	136
MarrB	15	220	Bali R.	35	118
Roos G.	13	137	Kant R.	22	112
Lu W-K.	11	61	Wickramasinghe N.	21	95
Veltri S.	11	19	Smolnik S.	23	43
Average	**15,2**	**441,2**	**Average**	**28**	**205,3**

Despite the author Dumay has a high number of articles (19), Tab. 6 shows that Edvinsson, Mouritsen and Bontis are authors who have the higher numbers of citations in IC. The average of top ten authors is equal to 441,2 citations per author.
In KM, Jennex has the highest number of articles (51), but Wong and Anumba have the highest numbers of citations. The average of top ten authors is equal to 205,3 citations per author.

4.4 H index of authors in IC and KM

It consists to rank the articles of an author in descending order of citations, and find when the rank of the article is higher than the number of citations (Tab. 7). Heller is the author having the highest H index in IC.

Table 7. H Index of author Heller M. in IC

Article rank	Nber of citations	Article rank	Nber of citations	Article rank	Nber of citations	Article rank	Nber of citations
1	106	2	72	**3**	**14**	4	2

Fig. 5 shows the application of H index to the author “Heller".

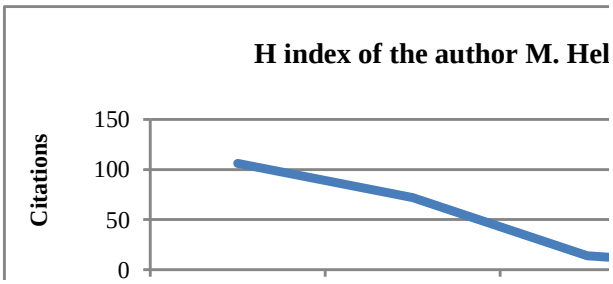

Figure 5. H Index of the author "M. Heller" of IC

In this case, the number of citations of the rank 4 is less than 4. Consequently, H index is this rank minus 1 (4-1=3). H index of Heller is 3.
In KM, the author who has highest H index is Wang.

Table 8. H Index of Wang J. in KM

Article rank	Nber of citations	Article rank	Nber of citations	Article rank	Nber of citations
1	306	5	17	9	8
2	168	6	15	…	…
3	56	7	11	22	0
4	43	**8**	**10**		

Fig. 6 shows the rank of articles of Wang in decreasing order of citations.

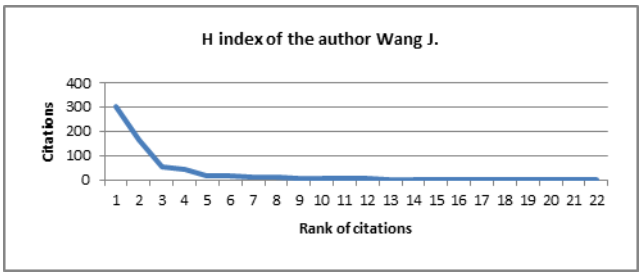

Figure 6. H Index of the author "Wang J." in KM

Note that the number of citations gradually decreases to the lack of citations. The index H in this case is 8.

4.5 G index in IC and KM

G index helps to make more apparent the difference between authors' respective impacts.

Table 9. G Index of IC and KM Authors

Author IC	G index IC	Author KM	G index KM
Bontis N.	∑citations>rank2	Wong K.Y.	∑citations>rank2
Mouritsen J.	∑citations>rank2	Anumba C.J.	∑citations>rank2
Edvinsson L.	∑citations>rank2	Edwards J.S.	∑citations>rank2
Guthrie J.	∑citations>rank2	Akhavan P.	13
Marr B.	∑citations>rank2	Gottschalk P.	12
Roos G.	11	Jennex M.E.	11
Dumay J.	9	Kant R.	10
Lu W-K.	7	BaliR. K.	9
AbeysekeraI	6	Wickramasinghe N.	9
Veltri S	4	Smolnik S.	6
Average	**7,4**	**Average**	**10**

In Tab. 9, it is found in IC that the greater value of G index (11) is marked by Roos, followed by Dumay (9) and Lu (7). With an index G equal to 7. Finally, Gutherie J., Mouritsen, Marr, Bontis and Edvinsson do not have G index because the sum of their citations is greater than their rank². The latter have better impact on research.
The highest G value in KM is marked by Akhavan (13), and authors: Wong, Anumba, Edwards, do not have G index because the sum of their citations is greater than their rank².

4.6 I index in IC and KM

The "immediacy index" allows determining whether a review has an immediate impact or furthering away in time.

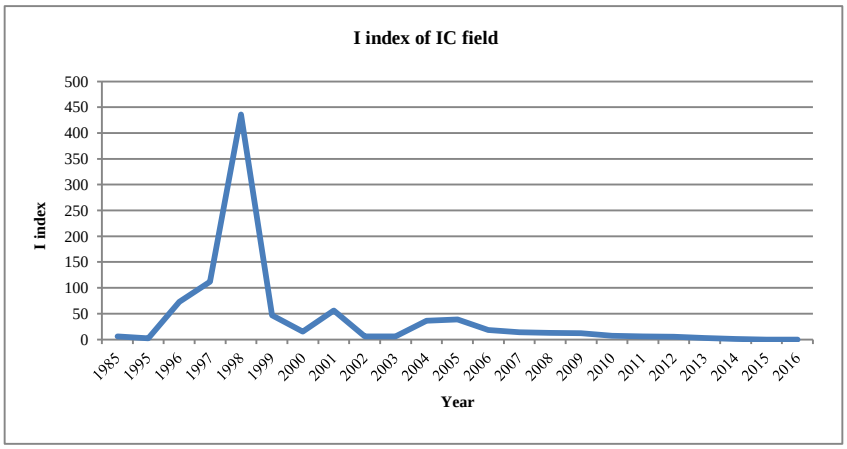

Figure 7. The “immediacy index" in IC.

Fig. 7 shows the “immediacy index” in the field of IC. There has been a rapid increase from 1995 to reach the summit immediate citations in 1998 with value of followed by a decrease until 2016.

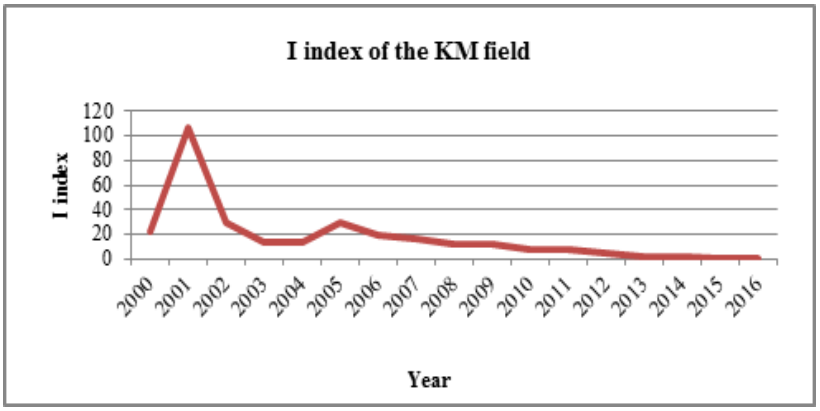

Figure 8. The "immediacy index" in KM.

Fig. 8 shows the "immediacy index" of KM field. There was an increase in 2000 to the peak in 2001. Since 2001, a slow decrease until 2005 and then falling steadily until 2016. Articles of IC (436) are cited more immediately than those of KM (107) after their publication.

4.7 N Index in the fields of IC and KM

It is calculated by dividing the H index by the number of years since first publication.

Table 10. H and N Indexes of a sample of authors in IC

Author	Year	H Index	N index
wacquant L.	1	7	7
Sapiro G.	9	4	0,44
Heller M	1	14	**14**
Affes H.	6	1	0,16
Flouri E.	1	4	4

Tab. 10 shows the N index on a sample of 5 authors of IC field and the larger value is up to the author Heller. His H index is the highest and the number of years is the lowest. Contrary to the authors Affes and Sapiro that the value of the average H index and many years of work decreased their N index (Fig. 9).

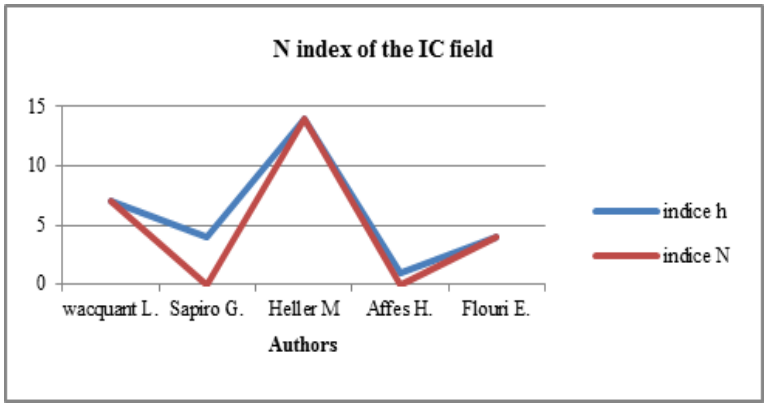

Figure 9. H and N indexes of sample of authors in IC.

H and N indexes were calcultaed for a sample of 4 authors in KM (Tab. 11).

Table 11. H and N Indexes of a Sample of Authors in KM.

Author	Number of years	N index	H index
Kant R.	9	0,66	6
Wang J.	9	0,88	8
Wickramasinghe N.	13	0,38	5
Smolnik S.	9	0,33	3

The highest value returns to Wang. The authors Kant and Wickramasinghe, have a high H index and a high number of years, so their N index is low. The publications of IC are the latest and most cited unlike KM which are older and less cited (Fig. 10).

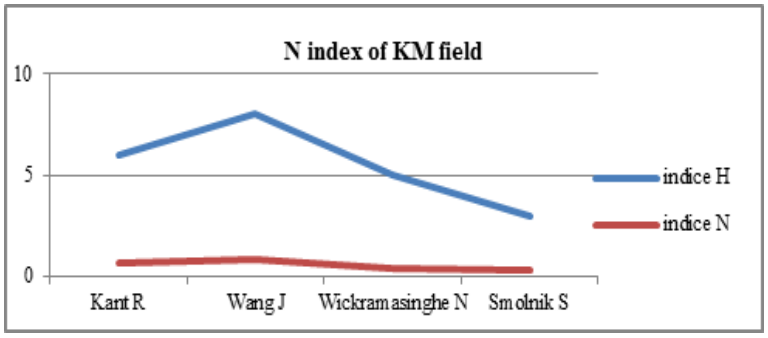

Figure 10. H and N index on a sample of four authors in KM.

4.8 i10 index in IC and KM

Only used in Google scholar, it considers only the authors with citations greater than 10. It is used in this work for SCOPUS.

Table 12. i10 Index in IC and KM

Author IC	i10 IC	Author KM	i10 KM
Bontis N.	18	Edwards J.S.	9
Mouritsen J.	11	Wong K .Y.	8
Dumay J.	9	Anumba C.J.	7
Guthrie J.	9	Akhavan P.	7
Marr B.	7	Gottschalk P.	7
Abeysekera I.	6	Jennex M.E.	4
Edvinsson L.	6	Bali RK.	3
Roos G.	6	Kant R.	3
Lu W-K.	3	Wickramasinghe N.	2
Veltri S.	---	Smolnik S.	1
Average	**8,33**	**Average**	**5,1**

In Tab. 12, Bontis has the highest i10 index in IC (18), followed by Mouritsen (11) and, Dumay and Guthrie (9). Contrary to Veltri S. does not have i10 index (0), because he does not have any article with at least 10 citations. Edwards has the highest i10 index in KM (9), followed by Wong (8) and Anumba (7). Smolnik has the lower i10 index (1), he has only one article with 10 citations.

4.9 Lotka's law in IC and KM

It states that the number of authors publishing articles is inversely proportional to the square of published articles.

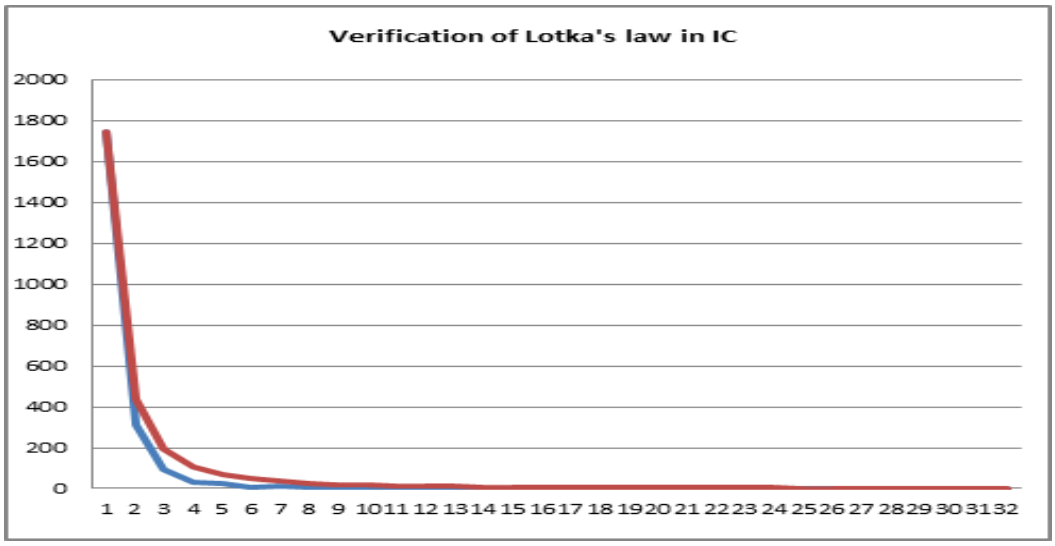

Figure 11. Correspondence of results to Lotka's law in IC

In Fig. 11, the curve in blue represents the theoric Lotka's law and the brown one represents the existing Lotka's law calculated from IC articles in SCOPUS database. Almost existing articles follows Lotka's law, except in the middle of the curves slightly different. This only means that the sample is representative.

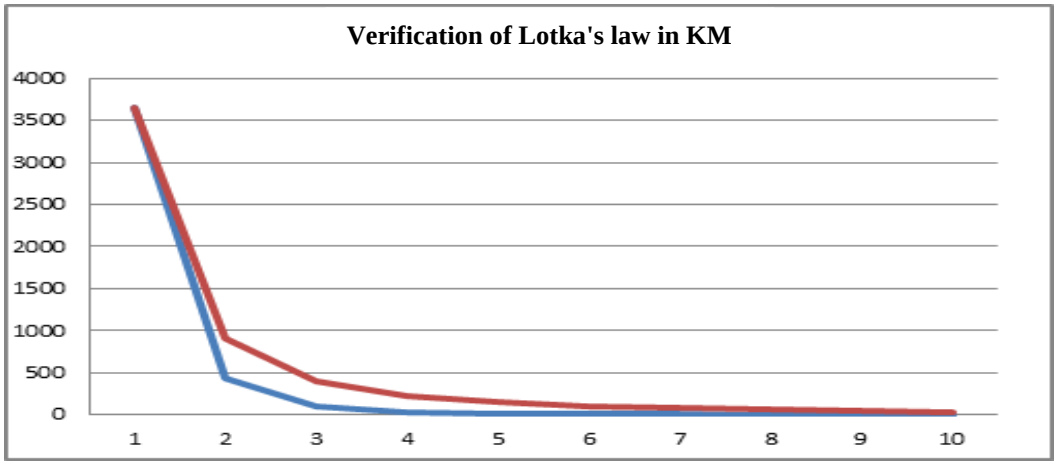

Figure 12. Correspondence of results to Lotka's law in KM

Fig. 12 represents the existing and the theoric curves of Lotka's law calculated from KM articles in SCOPUS. Almost existing articles follows Lotka's law except in the middle of the curves more different than in IC case.

5 Comparison of IC and KM in Generic Bibliometric Indexes

Tab. 13 shows a summary and averages of applied indexes to IC and KM. Despite the sample of KM (1998 articles) is larger than the sample of IC (1504 articles), we find that the average number of references par article IC (44,12) is larger than KM (33,65); this is explained by the power contents of documents of IC relatively. Contrary to H and G indexes which are greater in KM (8; 10) compared to IC (3,7; 4) thanks the reputation and notoriety of KM. I and N indexes in IC (436; 14) are greater than KM (107; 0,88) ones; ie the articles of IC are cited more immediately than articles in KM and also over time.

In KM the number of articles cited at least 10 times for the top ten productive authors is 5,6 and lower than IC (8,33) one; we understand that in IC there is low number of authors but they are more productive and cited than KM authors.

Lotka's law in IC is almost valid and less valid in KM; it is related to the representativeness of their samples.

Table 13. Summary of IC and KM Indexes

Index / field	Articles	references	Nber citations /article		most cited Author	
IC	1504	44 ,12	13,92		N. Bontis	
KM	1998	33,65	15,29		K. Y. Wong	
Index / field	**Highest H index of authors**	**G Index**	**i10 index**	**Highest immediacy index**	**Highest N index**	**Lotka's law**
IC	3 M. Heller	7,4	8,33	436	14	valid
KM	8 J. Wang	10	5,1	107	0,88	Less valid

6 Conclusion

In global view, in this work it was found that intellectual capital is emerging field and scientific researchers are more productive and have immediate impact than those of knowledge management field, despite its novelty.
This study could be extended to other databases (WOS, INSPEC…etc.), to have more representative dataset of a field and with adaptation of computing programs.
The impact of research is analyzed and measured using relative bibliometric indexes. Currently, bibliometry finds its most important application in evaluating the performance of scientific research. More recently, bibliometric methods have been used to assess the effectiveness and productivity of research.
After the global bibliometric analyses of authors of articles, and the application of the few indexes that have presented beforehand on the programming language R, the results obtained have been compared, the aim of which is to highlight the best destination that contains the information.
It is believed that this work was very beneficial for us. We are now able to easily program any other index and find the desired information and using the R language that is now in hand, it is now a rewarding professional experience and encouraging for our future.
Finally, and as an outlook for this work, these indexes can be applied to other research areas or other specific queries and propose a complete and user-friendly application for bibliometry.

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