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Hirsch-type indices and library management: the case of Tongji University Library[1]

Yuxian Liu[1] and Ronald Rousseau [2,3,4]

[1] *E-mail: yxliu@lib.tongji.edu.cn*
Catalogue Section, Library of Tongji University
Siping Street 1239, 200092 Shanghai, P.R. China

[2] *E-mail: ronald.rousseau@khbo.be*
KHBO (Association K.U.Leuven), Department of Industrial Sciences and Technology, Zeedijk 101, B-8400 Oostende, Belgium;

[3]University of Antwerp (UA), IBW, Universiteitsplein 1, B-2610 Wilrijk, Belgium

[4]Hasselt University (UHasselt), Agoralaan, Building D, B-3590 Diepenbeek, Belgium

Abstract
Hirsch-type indices are applied in a library management context. In this article quantitative, statistical approaches as well as a qualitative discussion are used to study the case of Tongji University Library. A comparison is made between the properties of different Hirsch-type indices. It is further shown that Hirsch-type indices can illuminate the reading interests of readers as shown by their use of a library's collection, hence expanding the field of application of such indicators.

Keyword: Hirsch index; g-index; $H^{(2)}$-index; Inequality measurement; Library management; Reading interests

Introduction

The h-index, recently proposed by J. Hirsch (2005) has attracted a lot of attention among scientometricians. Although introduced in a publication-citation context, it can easily be applied in many other source-items settings. In this article we intend to show that the Hirsch index, the g-index and the $H^{(2)}$-index (definitions are provided in the next section) can be used as indicators in a library management setting. As a case study we chose Tongji University Library as one of us works there and has access to the relevant data.

In this article the original h-index, the g-index and the $H^{(2)}$-index will be referred to as Hirsch-type indices. It is the purpose of this contribution to show how these indices are useful tools for library management.

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The Hirsch index

Let us consider the list of publications [co-]authored by scientist S, ranked according to the number of citations each of these publications has received. Publications with the same number of citations are given different rankings (the exact order does not matter). Then S' Hirsch index is h if the first h publications received each at least h citations, while the publication ranked h+1 received strictly less than h+1 citations (Hirsch, 2005; Rousseau, 2006b). It is further noted that if the last article in the list occupies rank R and if it receives C > R citations then this scientist's h-index is set equal to R.

Although the h-index is a relatively simple indicator it attracted a lot of attention (Ball, 2005; Bar-Ilan, 2006; Bornmann & Daniel, 2005; Cronin & Meho, 2006; Glänzel, 2006a,b; Glänzel & Persson, 2006; Jin, 2006; Rousseau, 2006a; van Raan, 2006). Being indeed a relatively simple indicator a number of advantages and disadvantages are quite obvious. Following (Glänzel, 2006a; Hirsch, 2005) we note the following ones.

Advantages

- The h-index can be applied to any level of aggregation.
- It combines two types of activity (in the original setting this is citation impact and publications).
- It is a mathematically simple index.
- It is a robust indicator, see also (Rousseau, 2007). Increasing the number of publications alone does not have an immediate effect on this index.
- Single peaks (top publications) have hardly any influence on the h-index.
- In principle, any document type can be included.
- Unimportant (hardly ever cited) publications do not influence the h-index.

Disadvantages

- The h-index, in its original setting (Hirsch, 2005), puts newcomers at a disadvantage since both publication output and observed citation rates will be relatively low.
- The index allows scientists to rest on their laurels since the number of citations received may increase even if no new papers are published.
- This indicator is based on long-term observations. It can, moreover, never decrease.
- Like most pure citation measures it is field-dependent.
- There is a problem finding reference standards.
- There exist many more versatile indicators (van Raan, 2005).
- It is rather difficult to collect all data necessary for the determination of the h-index. Often a scientist's complete publication list is necessary in order to discriminate between scientists with the same name and initial.

It has been observed that (in the original context of publications and citations) the h-index is only weakly sensitive to the number of citations received. Indeed, when a scientist's h-index is equal to h then this scientist's first h articles received at least h times h, i.e. h^2 citations. For a given value of the h-index, this lower bound is the only relation that logically exists between publications and citations.

Hirsch-type indices

Because of this weak sensitivity with respect to the actual number of citations received, Leo Egghe proposed another index referred to as the g-index (Egghe, 2006a,b). This g-index is calculated as follows: one draws the same list as for the h-index, but now the g-index is defined as the highest rank such that the cumulative sum of the number of citations received is larger than or equal to the square of this rank. Clearly $h \leq g$. A scientist who writes many articles which are each well-received, but not exceptionally well, will have a high h-index. His g-index will just be marginally larger than his h-index. Stated otherwise the ratio of g/h will be close to 1 (but never smaller than 1!). A scientist who writes a few exceptional articles (maybe some reviews), while her other articles are hardly noticed by the scientific community will have a relatively low h-index and a high g-index. Examples of such

cases are shown in (Rousseau, 2006b). Taken together, g and h present a concise picture of a scientist's achievements in terms of publications and citations.

Recently, another index has been proposed by Marek Kosmulski (2006). This index, denoted as $H^{(2)}$ is defined as follows. Consider again the list of publications [co-]authored by scientist S, ranked according to the number of citations each of these publications has received. Then this scientist's $H^{(2)}$-index is k if k is the highest rank (largest natural number) such that the first k publications received each at least k^2 citations. Obviously: $H^{(2)} \leq h$. According to Kosmulski, the main reason for the introduction of this index is that it reduces the work of checking names, corresponding publications and received citations, and is still highly correlated with the total number of citations received.

It is clear that Hirsch-type indices can not only be used to evaluate lifetime publication-citation achievements, but also in the context of many other source-item relationships (Braun et al., 2005; Egghe & Rousseau, 2006). One of these other applications, illustrated in this article, is the case of library books as sources of loans in a university library. In this context the definition of a Hirsch index for loans is rephrased as follows. Consider the list of a collection of books in a library (it may also be the collection of all books in a particular branch library or book category) and the number of times these books were on loan during a fixed period. This list is ranked according to the number of loans (in decreasing order). Books with the same number of loans are given different rankings (again, the exact order does not matter). Then the Hirsch index for loans of this collection is h if h is the highest rank such that the first h books were on loan each at least h times. We will apply this definition for categories of books, and not for a library as a whole.

Tongji University and its Library Classification System

Tongji University is a comprehensive university situated in Shanghai and offering courses in engineering, science, medicine, management, arts, law and economics. It has special strengths in architecture, civil engineering and oceanography. Indeed, in a recent report Tongji University ranked among the top 5 Chinese universities in architecture, urban planning, civil engineering, environmental sciences, traffic and transportation engineering, equipment engineering and engineering management (Qiu et al., 2006).

The history of Tongji University can be traced back to 1907 when Tongji German Medical School was founded by Erich Paulun, a German doctor living in Shanghai. As the result of a nationwide reorganization Tongji University became in 1952 a university with strengths in engineering, focusing on civil engineering. Since then the university gradually developed to be a comprehensive university, strong in engineering but also offering programs in science, economics, management, arts and law. In 1996 Tongji University merged with Shanghai Institute of Urban Construction and Shanghai Institute of Building Materials. In April 2000, the expanded Tongji University merged with Shanghai Railway University. In this way the university consists of several campuses covering a total area of 141.8 hectares: Main Campus (including South Campus), Hudong Campus, Hubei campus, Huxi Campus, and Jiading Campus, a new campus situated inside Shanghai International Automobile City, a suburban district of Shanghai. There are libraries at each campus, except for the South Campus, which is served by the Main Library (situated at the Main Campus). Since 1978 the university restored its special relationship with Germany, resulting in the establishment of the Chinese-German University College. Nowadays Tongji University registers more than 50,000 students at all levels of education (bachelor, master, doctoral and post-doctoral). There are over 4,200 academic staff members for teaching and/or research.

Tongji University Library applies the Chinese Library Classification System (CLC), a comprehensive library system used in most libraries, information institutes and centres in China. The Chinese Academy of Sciences, however, uses another system. The CLC system has gone through several revisions, its most comprehensive one dating from 1999. According to the CLC system there are 22 main categories, shown in Table 1. These main categories are further subdivided into subcategories.

Table 1. Chinese Library Classification System

A	Marxism, Leninism and Chinese communism
B	Philosophy and religion
C	Social sciences
D	Politics and law
E	Military sciences
F	Economics
G	Culture, science (of sciences), education
H	Languages (incl. linguistics)
I	Literature
J	Arts
K	History and geography
N	Natural sciences (general)
O	Mathematics, physics and chemistry
P	Astronomy and geosciences (incl. marine sciences)
Q	Bioscience
R	Medicine and hygiene
S	Agricultural science (including forestry)
T	Industrial technology
U	Transportation
V	Aviation and spaceflight
X	Environmental sciences
Z	Others

As Tongji University is a university specializing in science and engineering we will also use the subcategories of category T: Industrial technology. These subcategories are shown in Table 2.

Table 2. Subcategories of category T: Industrial technology

TB	Fundamental engineering technology
TD	Mining engineering
TE	Oil and natural gas industry
TG	Metal industry
TH	Mechanics
TJ	Weapon industry
TK	Dynamics and sources of energy
TL	Atomic energy technology
TM	Electrotechnics
TN	Wireless electronics and telecommunication technology
TP	Computer science
TQ	Industrial chemistry
TS	Light industry
TU	Architecture and urban planning
TV	Water conservation and irrigation

Data collection

Data are obtained from the loan records of the Library of Tongji University, consisting of a Main Library and four branch libraries. The Main Library is situated at the Main Campus (also referred to as Siping Campus) in the centre of Shanghai. Branch libraries are located on four other campuses: Huxi, Hudong, Hubei and Jiading Campus. The Huxi branch library serves mostly freshman students. Senior undergraduate students study on Main campus. Hudong library serves mostly master and doctoral students; Hubei library serves mostly vocational students. While these campuses and their libraries are also situated in Shanghai, Jiading Campus is a new campus located within Shanghai Jiading International Automobile City, somewhat outside the centre, and built for over 15,000 students. It received its first students in September 2004. Students at Jiading Campus specialize in automobile related subjects and software engineering.

Branch libraries apply different policies as to which books are kept in the reading room and which are available for regular check-out. In Huxi library books in categories B, C, D, F, G, H, O, and T are

transferred from regular check-out to the reading room, once it is clear that they are in demand. In Hudong library, all books published after 2000 were transferred to the reading room, while all older books are available for regular check-out. Finally, Hubei library transferred all medicine books to the Main Library, but does not do any other transfers. The most recent books, though, are only available in the reading room.

Library loan data for each library (five in total) were collected in August 2006 and cover the period March 21, 2001 till July 31, 2006. The beginning date coincides with the introduction of a computerized library loan system for the whole university. Tongji University uses the Huwen Library System software. This library software contains several statistical functions, but we only use the function which ranks books according to the number of loans. In each library the software provided us with data for the reading room (or reading rooms) and general check-out separately. Jiading Campus Library, however, has only reading rooms for the moment. Moreover, data for this library cover only a two-year period. All these data were copied in an Excel spreadsheet in order to calculate the Hirsch index, the g-index and the $H^{(2)}$-index. Usually the library owns several copies of a book. In those cases all loans are brought together leading to exactly one number (of loans) for each title.

Structural and statistical data analysis

The Hirsch-index, g-index and $H^{(2)}$-index are calculated for each class in each library, and this for the reading room(s) and regular check-out separately. In terms of sources and items, each class is considered a source (playing the role of the authors in Hirsch's original setting) while loans are items (playing the same role as citations in Hirsch' original setting). Table 3 shows the results for the Main Library (R stands for Reading room; C for check-out). The first number gives the rank, while the second number gives the value of the index. Results for the other libraries can be obtained from the authors. For example, class TP (*Computer science*) is always number one in the Main Library's reading room. For the reading room it has an $H^{(2)}$-value of 4, an h-value of 15 and a g-value of 19. Compared to other categories, books on computer science are somewhat less popular for check-out: in this list computer science books occupy the fifth place. Values of the indices, however, are much higher for check-out than for the reading room: $H^{(2)} = 13$, $h = 105$ and $g = 131$. This phenomenon only occurs in the Main Library. At the other libraries the opposite is true.

On logical grounds the inequalities $H^{(2)} \leq h \leq g$ always hold. Interestingly, we observed some non-trivial equalities for h and g. For instance loan data in class V: "Aviation and spaceflight" for the Jiading reading room are shown in Table 4. Clearly the h-index is equal to 4 (the book at rank 4 is loaned out 5 times, while the book at rank 5 is loaned out only 4 times). The g-index is also equal to 4 as $4^2 = 16 < 20$ (the cumulative number of loans for the first 4 books), while $5^2 = 25 > 24$ (the cumulative number of loans of the first 5 books).

Do different Hirsch-type indices lead to the same ranking of library classification classes? Are these ranking the same for reading room data as for check-out data? We tried to answer these questions by calculating Spearman rank correlation coefficients. Table 5 shows the results for the Main Library. Correlations are generally high, and are especially high when correlations between the three Hirsch-type indices for the reading room, and between the check-out data are compared (in bold). Similar tables were obtained for the branch libraries and can be obtained from the authors.

Table 3. Main Library (rank followed by value of the Hirsch-type index in the cells)

		$H^{(2)}$ - R	$H^{(2)}$-C	h - R	h - C	g -R	g-C
A	Marxism- Leninism and Chinese communism	28-1	26-6	28-2	25-27	30-2	26-36
B	Philosophy and religion	14-2	8-11	14-5	7-80	19-5	8-101
C	Social sciences	14-2	8-11	10-6	11-69	14-6	11-91
D	Politics and law	14-2	16-9	14-5	15-56	14-6	15-71
E	Military sciences	28-1	23-7	28-2	26-25	25-3	25-39
F	Economics	5-3	5-13	10-6	6-92	7-9	6-121
G	Culture- science (of sciences)- education	14-2	19-8	19-4	19-41	22-4	19-56
H	Languages (incl. linguistics)	5-3	3-15	10-6	3-139	12-9	3-177
I	Literature	5-3	1-16	7-7	2-148	10-8	2-186
J	Arts	14-2	7-12	19-4	8-78	19-5	7-105
K	History and geography	14-2	8-11	19-4	8-78	19-5	8-101
N	Natural sciences (general)	14-2	23-7	24-3	23-28	25-3	22-43
O	Mathematics- physics and chemistry	5-3	3-15	3-12	4-110	5-14	4-149
P	Astronomy and geosciences (incl. marine sciences)	14-2	16-9	14-5	17-43	14-6	18-58
Q	Bioscience	5-3	19-8	14-5	20-37	12-7	20-53
R	Medicine and hygiene	1-4	23-7	5-11	22-31	3-16	22-43
S	Agricultural science (including forestry)	28-1	26-6	24-3	29-19	25-3	30-29
TB	Fundamental engineering technology	1-4	12-10	3-12	14-57	4-15	13-81
TD	Mining engineering	32-0	32-0	32-0	32-0	32-0	32-0
TE	Oil and natural gas industry	32-0	32-0	32-0	32-0	32-0	32-0
TG	Metal industry	14-2	26-6	19-4	28-22	22-4	27-35
TH	Mechanics	14-2	12-10	14-5	16-51	14-6	15-71
TJ	Weapon industry	32-0	32-0	32-0	32-0	32-0	32-0
TK	Dynamics and sources of energy	14-2	19-8	24-3	21-34	22-4	21-48
TL	Atomic energy technology	32-0	32-0	32-0	32-0	32-0	32-0
TM	Electrotechnics	5-3	16-9	10-6	18-42	10-8	17-64
TN	Wireless electronics and telecommunication technology	5-3	12-10	6-10	13-64	6-13	13-81
TP	Computer science	1-4	5-13	1-15	5-105	1-19	5-131
TQ	Industrial chemistry	14-2	19-8	19-4	23-28	14-6	24-42
TS	Light industry	14-2	26-6	24-3	27-23	25-3	28-32
TU	Architecture and urban planning	1-4	1-16	2-14	1-149	2-17	1-188
TV	Water conservation and irrigation	14-2	26-6	28-2	30-18	25-3	29-30
U	Transportation	5-3	8-11	7-7	10-73	7-9	10-100
V	Aviation and spaceflight	28-1	26-6	31-1	31-16	30-2	31-22
X	Environmental sciences	5-3	12-10	7-7	12-66	7-9	12-87

Table 4 Loans in Jiading reading room, class V

Rank	$(Rank)^2$		Number of loans	Cumulative number of loans
1	1	Book A	5	5
2	4	Book B	5	10
3	9	Book C	5	15
4	16	Book D	5	20
5	25	Book E	4	24
6	36	Book F	4	28
…	…	…	…	…

Table 5. Rank correlation according to Hirsch-type indices between library classification classes (Main Library)

	$H^{(2)}$-R	$H^{(2)}$-C	h-R	h-C	g-R	g-C
$H^{(2)}$-R	**1.0000**	0.7333	**0.9347**	0.7467	**0.9531**	0.7511
$H^{(2)}$-C		**1.0000**	0.8187	**0.9900**	0.7943	**0.9925**
h-R			**1.0000**	0.8306	**0.9810**	0.8270
h-C				**1.0000**	0.7965	**0.9979**
g-R					**1.0000**	0.7956
g-C						**1.0000**

Another important issue is whether these Hirsch-type indicators are able to separate sources, i.e. library classification classes in our case. We use the Gini coefficient, a measure of concentration, as an indicator of separation. Table 6 shows the values of the Gini coefficient between library classification classes for each library and each Hirsch-type index.

Table 6. Gini coefficients

	$H^{(2)}$	h	g
Main R	0.286	0.399	0.412
Main C	0.270	0.420	0.396
Huxi R	0.479	0.635	0.646
Huxi C	0.407	0.542	0.539
Hudong R	0.332	0.464	0.464
Hudong C	0.326	0.433	0.431
Hubei R	0.335	0.478	0.472
Hubei C	0.322	0.432	0.442
Jiading R	0.280	0.432	0.432
average	0.337	0.471	0.470

Not surprisingly, the $H^{(2)}$-index does not discriminate in the same way among classes as the h- and g-indices, leading to smaller values of the Gini coefficient. We see further that the average values of these inequality measures are very similar for the h- and the g-index. In Egghe's example of Price medallists (Egghe, 2006c) the g-index discriminates more than h-index, but, of course, the type of data studied there is totally different from ours.

Qualitative data analysis

In this section we discuss some interesting observations about the actual Tongji data. Hirsch-type indices are always higher for the reading rooms than for check-out in Hudong and Hubei branches, while for the Main Library the opposite is the case. Huxi library shows a mixed pattern. This may be explained by the fact that in some branch libraries (Hudong and Hubei) books available for check-out are usually older books, and hence for some fields less interesting. These older books are mainly the older collections, namely those obtained before the local university merged with Tongji University. This observation suggests that newer books have a higher Hirsch-type index for loans than older ones (under the same loan conditions). *Computer science* usually ranks higher for reading room data than for check-out data. This can be explained by the fact that the most recent books are mainly consulted in the reading rooms. Huxi library shows a mixed pattern because books are transferred between reading room and check-out depending on the classification type. The different pattern for the Main Library is due to the fact that every book owned by Tongji University Library is available for loan at the Main Library.

We observe that values of the Hirsch-type indices are highest for Hudong Campus, followed by Huxi and Hubei, in that order. This illustrates the fact that master and doctoral students use more books than undergraduate students, who, in turn, use more books than vocational students.

Books in the categories H (*languages*), I (*literature*), O (*Mathematics-physics-chemistry*), TP (*Computer science*) and TU (*Architecture and urban planning*) are usually among the top-5 in the rankings according to Hirsch-type index. The high scores for TU (*Architecture and urban planning*) illustrate the fact that this is the topic in which Tongji University excels (Qiu et al., 2006). Even at Jiading campus this category scores relatively high (between 10^{th} and 13^{th} position) although no architecture is taught at this campus.

Some smaller changes in Hirsch-type indices' ranks indicate differences in emphasis in different campus. In the Main Library the categories *Medicine and hygiene* and *Fundamental engineering technology* rank high, but only for the reading rooms. For *Medicine and hygiene* this may be explained by the fact that the valuable medicine books have been transferred from Hubei library (formerly the library of the medical university) to the Main Library. Moreover, all books on medicine are available in a reading room, leading to high Hirsch-type indices in *medicine and hygiene*. Scores for *fundamental engineering technology* can be explained by the fact that this category contains the books which are fundamental for most undergraduates in technologically oriented fields. In Huxi library *philosophy, religion and Marxism* also scores high, as do books on medicine and biosciences (check-out data). Medicine and biosciences score high because all books belonging to these categories are available for check-out. Moreover *philosophy, religion and Marxism* are compulsory courses for undergraduates. Category U (*Transportation*) scores very high at Jiading library, illustrating the fact that the Jiading campus specializes in automobile related subjects and software engineering (*Computer science* ranks first).

Jiading Library's average value for the h-index (reading room) is 19.9 which is of the same order as Hudong's (21.8) and Huxi's (16.5) and higher than Hubei's (10.9). Remembering that we have only data for the latest two year, this shows that this library is very successful and attracts many students to its premises.

Tongji Library has only few books on mining engineering (TD), oil and natural gas industry (TE), weapon industry (TJ), and atomic energy technology (TL). In some libraries such books are not even available. For this reason these categories can usually be found at the end of the ranked lists.

Discussion and conclusions

Applications of bibliometrics to library management have always been an integral part of the information sciences (Burrell, 1980; Egghe & Rousseau, 1990; Leemans et al., 1992; McCain, 1997). In this article we have shown that also the latest developments in the field, i.e. the Hirsch-type indices, can be applied to library management issues. Hirsch-type indices can illuminate the reading interests of readers as shown by their use of a library's collection. Consequently, changes in these indices may reflect changes in users' interest. Yet, they may also reflect changes over time in the quality of different collections.

In this article we considered rather straightforward applications of the original definitions of the Hirsch-type indices. We ask as a research question: could another (related) index be invented which is particularly suited for use in a library management environment?

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