Methodology of calculation and structural analysis of Journal Impact Factor based on the Web of Science: A case study of *Nature*

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ABSTRACT

In this paper, we take Nature *as a case study to present a new method for calculating and analyzing the structure of the Impact Factor (IF) using the Web of Science (WoS) database and the definition of IF. We calculated* Nature*'s IF for 2013 using data retrieved on 21 March 2014 from the WoS database and comprehensively analyzed its structural features, thereby identifying the contributions to* Nature*'s IF for 2013 of different document types, highly cited papers, highly cited authors, different institutions, and different countries and regions. The results show: (a) the calculated value of* Nature*'s IF for 2013 is 41.002 according to data retrieved in March of 2014; (b) two types of document, article and review, made prominent contributions to* Nature*'s IF for 2013, with contribution values of 35.338 and 3.179, respectively; (c) the institutions that made the greatest contributions to* Nature*'s IF for 2013 are mainly located in the USA and England, with the first three highly cited institutions being Harvard University, Stanford University, and Washington University; (d) the contributions of different countries and regions to Nature's IF for 2013 differ greatly, with the combined contribution rate of the USA and England being 70.4 percent.*

Keywords: *Nature*; Journal studies; Impact factor; Structural analysis; Bibliometrics

INTRODUCTION

Nature, the world's most highly cited interdisciplinary science journal, is published by the Nature Publishing Group, an independent British commercial publisher, and is viewed as the publisher's "flagship". Not only has it been recognized by Elsevier as the most influential journal, but it also enjoys widespread influence and high prestige internationally (Pai 2009). In China, *Nature* is attracting increasing attention among the academia; especially in recent years, where many universities and research institutions have established incentive policies to encourage researchers to publish more papers in *Nature*. For example, China Agricultural University, South China Normal University, and Zhejiang Sci-Tech University each award one million yuan (RMB) per paper published in *Nature*. The Xinxiang Medical University has recently declared an award of one million yuan per paper published in *Nature* or any of its series having an impact factor (IF) of 20 or greater. Yangzhou University and Nanjing University award 0.5 million and 0.3 million yuan per

paper respectively; Nankai University, Harbin Institute of Technology, and Nanjing University of Aeronautics and Astronautics have announced an award of 0.1 million yuan per paper published in *Nature*. It is also widely recognized that *Nature* is not only used for determining monetary awards in the Chinese scientific evaluation system, but it is also commonly used in the selection of academicians to the Chinese Academy of Sciences and the Chinese Academy of Engineering.

Garfield (1955), first proposed the term IF in his paper published in *Science*, referring to citations to articles. Later Garfield and Sher (1963) proposed IF as an indicator for evaluating the academic impact of journals in 1963, after which IF was applied to assist the selection of source journals in the Science Citation Index (SCI) database. With the launching of the Journal Citation Reports (JCR) in 1976, the IF has been viewed as an important journal evaluation indicator and has increasingly gained wider attention and application (Betz 2014; Campanario 2011a; Servaes 2014). However, with the increasingly widespread use for journal evaluation, the IF exposed several defects and caused much abuse and misuses. For example, it is not only used in measuring the research performance of scientists (Holden et al. 2006; Shao and Shen 2012), institutions (Kim and Kim 2000; Liu 2012), and countries (Ugolini and Casilli 2003; Jokic 2003), but also in administering academic appointments, evaluating grant applications, and allocating other financial support for research programs (Adam 2002). Knowing the IF of certain journals in advance can not only help authors in selecting journals to which to submit their work, but also help editors take steps to increase their respective journals' IF accordingly. Thus, it is important to understand the methodology of the calculation and the structure of the journal IF.

There have been few studies performing a prediction or structural analysis of the journal IF. Wu, Fu and Rousseau (2008) discussed two methods for predicting IF in detail and explained why it was useful to derive one's own journal IF. Kovacic (2004) analyzed the structure of the 2003 IF for the *Croatian Medical Journal* (*CMJ*) and studied the effect of different kinds of citation on the IF of this journal. However, she only studied the contribution of article type to *CMJ*'s IF in the structural analysis. Campanario et al. (2006) studied the structure of the IF of academic journals based on a calculation of the fraction of citations that contribute to the IF of a given journal. However, he only studied the structure of citations and papers highly cited by the editorial board members. The limitation in the scope of investigation calls for significant analysis. Thus, it is still of great significance to analyze the structure of the IF in more detail.

For this study, we selected *Nature*, a journal with high IF, as a case study to present a new approach to calculate and analyze the structure of the IF using the Web of Science (WoS) database (Andrade, Gonzalez-Jonte and Campanario 2009; Campanario 2011b). More importantly, taking *Nature* as an example, we not only show a method for calculating the journal IF but also make a full study of its structural features, including the contributions of different document types, highly cited papers, highly cited authors, different institutions, and different countries as well as regions.

METHOD

Method of Computation for *Nature*'s IF for 2013

Document types published by *Nature* in 2011 and 2012 include articles, reviews, editorial materials, news items, book reviews, letters, corrections, and biographical items. Only articles and reviews are counted as citable items, which is the denominator in the formula

for calculating a journal's IF (Simons 2008; Vanclay 2011). The numerator in the formula for the calculation of IF is the total number of citations of all documents in a given year. It is obvious that all document types can have an effect on the IF. We counted the number of papers published by *Nature* in 2011 and 2012 of each document type and their total citations in 2013 to calculate *Nature*'s IF for 2013. The document retrieval date was 21 March 2014.

The IF for a given year is calculated by dividing the number of citations of items published in the previous two years by the number of citable items published in those same years. For example, the 2013 IF is obtained as follows:

$$\text{Impact Factor (2013)} = \frac{\textit{Citations in 2013 of documents published in 2011 and 2012}}{\textit{Citable items published in 2011 and 2012}}$$

In our retrieved data, there were 1710 articles and reviews published by *Nature* from 2011 to 2012, and the total citations in 2013 of all documents were 70,114. By using the above formula we know that *Nature*'s IF for 2013 is 41.002. In addition, we calculated the IF for *Nature* for the years 2008 to 2012, and accordingly we retrieved *Nature*'s actual IF from the JCR database for comparison. We then calculated the prediction error for each year. With a prediction error of 2.537 percent in 2012, the predicted value of *Nature*'s IF for 2013 is 42.027. Detailed results are shown in Table 1.

Table 1: Calculated Value and Prediction Error of *Nature*'s IF from 2008 to 2012

Year	Citation count*	Number of papers**	Calculated value	Actual value	Error rate
2012	64105	1703	37.642	38.597	2.537%
2011	63719	1728	36.87442	36.28	-1.612%
2010	63999	1773	36.09645	36.104	0.021%
2009	61053	1750	34.88743	34.48	-1.168%
2008	57088	1806	31.61019	31.434	-0.557%

*Citation count in the given year of papers published in the previous two years. **Number of articles and reviews. Calculated value = (citation count)/(number of papers); actual value is retrieved from the JCR database.

It is evident from Table 1 that although there are some errors between the calculated values for *Nature*'s IF and its actual value, all errors remain under 2 percent, except in 2012. The error rate for 2010 is only 0.021 percent, which supports the credibility of this method of calculation for the IF. In addition, the calculated values of *Nature*'s IF are higher than its actual values in 2008, 2009, and 2011. We deduce that the possible reasons may be due to:

(a) Errors that can take place when authors cite references because there are differences between the JCR database and the WoS database. For example, we searched the citations and the numbers of papers required to calculate the IF from 2008 to 2012 on the WoS database and the JCR database, and found that the only factor causing the difference between the calculated value of the IF and the actual value was the inconsistency in citation.

(b) Time factor: Individual papers can be cited after the JCR database has published the IF, which causes the number of citations used to calculate the IF from the WoS database is higher than that used in the JCR database.

(c) Error handling and processing of the database: Our previous study showed that there were over 1,820,000 data processed by the WoS database in 2012 alone, so it would be difficult to avoid the possibility of mistakes in the journal citation data, which may lead in turn to errors in the calculation of the IF (Liu 2014a).

Structural Features of *Nature*'s IF for 2013

(a) Contribution of Different Document Types to *Nature*'s IF for 2013

Citations vary by document type. The types of documents published by *Nature* in 2011 and 2012 are as stated earlier. Table 2 details the number of papers of different document types and the contribution of each type to *Nature*'s IF for 2013.

Table 2: Contribution of Different Document Types to *Nature*'s IF for 2013

Document type	Number of papers	Citation counts	Citation per paper	Contribution to IF	Percentage of contribution
Article	1639	60428	36.87	35.338	86.19%
Review	71	5436	76.56	3.179	7.75%
Editorial material	1703	2826	1.66	1.653	4.03%
News item	819	919	1.12	0.537	1.31%
Letter	560	443	0.79	0.259	0.63%
Correction	168	39	0.23	0.023	0.06%
Book review	241	19	0.08	0.011	0.03%
Biographical item	41	4	0.10	0.002	0.01%
Total	5242	70114	13.38	41.002	100%

Table 2 shows that articles and reviews received the highest citation counts among the eight document types. Articles made the greatest contribution to *Nature*'s IF for 2013, as compared to other document types, contributing 86.19 percent of the total citations, followed by reviews (7.75 percent). Findings indicate that although the number of reviews is far lower than the number of articles, but the rate of citations per paper for reviews is more than twice than that for articles. Although the number of papers for editorial materials type is slightly higher than the number of articles, the citation rate of editorial materials is far lower than that for the articles. Other document types make little contribution to *Nature*'s IF for 2013.

(b) Contribution of Highly Cited Papers to *Nature*'s IF for 2013

We retrieved all documents published by *Nature* in 2011 and 2012 from the WoS database and selected the papers with citation counts in 2013 greater than 200. We believe that the 18 most highly cited papers made a prominent contribution to *Nature*'s IF for 2013.

From Table 3, we can see that there are nine highly cited papers published by *Nature* from the USA, four from England, two from Germany, and one each from Spain, Japan, and Belgium. In addition, the citation count of the paper about the human genome by I. Dunham is much higher than that of the other papers, so it made the greatest contribution to *Nature*'s IF for 2013, with a contribution value of 0.392.

Table 3: Contribution of Highly Cited Papers to *Nature*'s IF for 2013

Corresponding author	Institution*	Country	Document title	Citation counts**	Contribution to IF
Dunham, I	European Bioinformatics Institute	England	An integrated encyclopedia of DNA elements in the human genome	671	0.392
Perou, CM	University of North Carolina	USA	Comprehensive molecular portraits of human breast tumours	359	0.210
Spellman, PT	University of California, Berkeley	USA	Integrated genomic analyses of ovarian carcinoma	322	0.188
Bork, P	European Molecular Biology Laboratory	Germany	Enterotypes of the human gut microbiome	296	0.173
McVean, GA	University of Oxford	England	An integrated map of genetic variation from 1,092 human genomes	293	0.171
Kucherlapati, R	Harvard University	USA	Comprehensive molecular characterization of human colon and rectal cancer	269	0.157
Shen, JR	Okayama University	Japan	Crystal structure of oxygen-evolving photosystem II at a resolution of 1.9 angstrom	263	0.154
Huttenhower, C	Harvard University	USA	Structure, function and diversity of the healthy human microbiome	261	0.153
Wolf, J	Max Delbruck Center for Molecular Medicine	Germany	Global quantification of mammalian gene expression control	248	0.145
Carmeliet, P	Flanders Institute for Biotechnology	Belgium	Molecular mechanisms and clinical applications of angiogenesis	245	0.143
Novoselov, KS	University of Manchester	England	A roadmap for graphene	240	0.140
Kellis, M	Broad Institute of MIT and Harvard	USA	Mapping and analysis of chromatin state dynamics in nine human cell types	232	0.136
Kobilka, BK	Stanford University	USA	Crystal structure of the beta(2) adrenergic receptor-Gs protein complex	223	0.130
Compston, A	University of Cambridge	England	Genetic risk and a primary role for cell-mediated immune mechanisms in multiple sclerosis	217	0.127
Guigo, R	Center for Gene Regulation	Spain	Landscape of transcription in human cells	215	0.126
Garraway, LA	Broad Institute of MIT and Harvard	USA	The Cancer Cell Line Encyclopedia enables predictive modelling of anticancer drug sensitivity	208	0.122
Levine, B	University of Texas Southwestern Medical Center	USA	Autophagy in immunity and inflammation	203	0.119
Gordon, JI	Washington University	USA	Human gut microbiome viewed across age and geography	203	0.119

*First-named institution of the corresponding author. **Citation count in 2013.

(c) Contribution of Highly Cited Authors to *Nature*'s IF for 2013

There are 5242 papers published in *Nature* during this period covered by the WoS

database, and 3335 of them have a citation count of at least 1; therefore the citation rate for *Nature* papers published within those two years is 63.62 percent. Out of the 5242 papers, 2964 papers have (56.5 percent) at least one citation in 2013, meaning that only about half of all published papers have made a contribution to *Nature*'s IF. The addresses of the corresponding authors of the 2964 papers are analysed to identify the contribution of highly cited authors to *Nature*'s IF for 2013. The results are shown in Table 4.

Of the 20 highly cited corresponding authors, there are 13 authors from the USA, 3 from England, 2 from Germany, and 1 each from Japan and Belgium. The two authors who made the greatest contribution to *Nature*'s IF for 2013 are I. Dunham, from the European Bioinformatics Institute in England, and B.K. Kobilka, from Stanford University in the USA, with contribution values of 0.392 and 0.364, respectively. In addition, the two authors who published the most papers during these two years are M. Meyerson and T.R. Golub from the USA, with 14 and 10 papers, respectively, and contribution values of 0.185 and 0.149, respectively.

Table 4: Contribution of Highly Cited Authors to *Nature*'s IF for 2013

Author*	Institution	Country	Citation counts	Number of papers	Citation per paper	Contribution to IF
Dunham, I	European Bioinformatics Institute	England	671	1	671.00	0.392
Kobilka, BK	Stanford University	USA	623	9	69.22	0.364
Perou, CM	University of north Carolina	USA	359	4	89.75	0.210
Spellman, PT	University of California, Berkeley	USA	322	2	161.00	0.188
Meyerson, M	Broad Institute of MIT and Harvard	USA	317	14	22.64	0.185
Gordon, JI	Washington University	USA	313	4	78.25	0.183
Levine, B	Univ. of Texas Southwestern Med Cen.	USA	307	3	102.33	0.180
Stevens, RC	Scripps research Institute	USA	302	3	100.67	0.177
Bork, P	European Molecular Biology Lab	Germany	296	2	148.00	0.173
McVean, GA	University of Oxford	England	293	1	293.00	0.171
Kucherlapati, R	Harvard University	USA	269	4	67.25	0.157
Ren, B	Ludwig Institute for Cancer Research	USA	264	6	44.00	0.154
Shen, JR	Okayama University	Japan	263	1	263.00	0.154
Huttenhower, C	Harvard University	USA	261	2	130.50	0.153
Guttman, M	Broad Institute of MIT and Harvard	USA	258	3	86.00	0.151
Golub, TR	Eli and Edythe L. Broad Institute	USA	255	10	25.50	0.149
Carmeliet, P	Flanders Institute for Biotechnology	Belgium	249	3	83.00	0.146
Wolf, J	Max Delbruck Cen. for Molecular Med.	Germany	248	4	62.00	0.145
Novoselov, KS	University of Manchester	England	240	1	240.00	0.140
Granier, S	Stanford University	USA	235	2	117.50	0.137

* The corresponding author.

(d) Contribution of Highly Cited Institutions to *Nature*'s IF for 2013

We analyzed the first-named institutions of the corresponding authors of the 2964 papers and identified the first 20 highly cited institutions – those who made the greatest contribution to *Nature*'s IF for 2013. The 20 highly cited institutions and their contributions are shown in Table 5.

There are 13 universities, 6 research institutes, and 1 research center among the first 20 highly cited institutions. In other words, the institutions making the most prominent contribution to *Nature*'s IF for 2013 are primarily research organizations and universities. Moreover, the first five institutions making the greatest contribution are universities. The results reveal that universities are important headstream for research output. In addition,

all of the first 20 highly cited institutions are located in the USA (16) and England (4).

Table 5: Contribution of Highly Cited Institutions to *Nature*'s IF for 2013

Institution	Country	Citation counts	Contribution to IF
Harvard University	USA	3242	1.896
Stanford University	USA	2536	1.483
Washington University	USA	2103	1.230
University of California, Berkeley	USA	1471	0.860
University of Alaska Fairbanks	USA	1431	0.837
Yale University	USA	1367	0.799
Broad Institute of MIT and Harvard	USA	1159	0.678
University of California San Diego	USA	1140	0.667
Massachusetts Institute of Technology	USA	1134	0.663
University of Cambridge	England	990	0.579
University of Texas S/Western Medical Center Dallas	USA	945	0.553
University of Oxford	England	838	0.490
Scripps Research Institute	USA	767	0.449
Memorial Sloan Kettering Cancer Center	USA	751	0.439
California Institute of Technology	USA	744	0.435
University of California, San Francisco	USA	709	0.415
Wellcome Trust Sanger Institute	England	695	0.406
European Bioinformatics Institute	England	671	0.392
University of North Carolina	USA	667	0.390
Rockefeller University	USA	639	0.374

(e) Contribution of Different Countries and Regions to *Nature*'s IF for 2013

The 2964 cited papers are from 48 countries and regions. The top 20 countries and regions that made the most outstanding contribution to *Nature*'s IF for 2013 are shown in Table 6 along with their contribution values. The USA made the greatest contribution to *Nature*'s IF for 2013, with a contribution value of 24.623, followed by England (4.236). The contribution rate of the USA and England to *Nature*'s IF for 2013 comes to 70.4 percent indicating that the USA and England are important country sources for *Nature*. In addition, Germany, Japan, Switzerland, Canada, France, and China have also made large contributions to *Nature*'s IF.

Table 6: Contribution of Different Countries and Regions to *Nature*'s IF for 2013

Country	Citation counts	Contribution to IF	Country	Citation counts	Contribution to IF
USA	42106	24.623	Spain	813	0.475
England	7243	4.236	Belgium	717	0.419
Germany	4598	2.689	Italy	595	0.348
Japan	2278	1.332	Sweden	541	0.316
Switzerland	1974	1.154	Israel	430	0.251
Canada	1520	0.889	Denmark	395	0.231
France	1485	0.868	Austria	388	0.227
China	1309	0.765	Scotland	385	0.225
Australia	1031	0.603	South Korea	250	0.146
Netherlands	922	0.539	Singapore	233	0.136

CONCLUSIONS

The study has taken *Nature* as a case to present a new method for calculating and analyzing the structure of the Impact Factor (IF) using the Web of Science (WoS) database and the definition of IF. We conclude that this computational method for journal IF is scientific and reasonable because firstly, the method for computing IF introduced in this paper strictly follows its original concept and calculation principle. Secondly, the data for predicting IF have the same source as the JCR database; all come from the WoS. Finally, we have also consulted the official technical service personnel from Thomson-Reuters regarding our computational method, and we received full confirmation of the method for the calculation of IF.

We have calculated the IF of *Nature* for the years 2008 to 2012 using the same method and compared them with their actual values (Table 1). The results of the comparison show that almost all of the calculated values are quite close to the actual values published by the JCR database, which supports the accuracy of our computational method from an empirical perspective.

The structural analysis of *Nature*'s IF for 2013 shows that the contributions to IF of different document types differ greatly. The articles and reviews made the greatest contribution to *Nature*'s IF for 2013, with a combined contribution rate of 93.94 percent; these earned more citation counts than other document types. In addition, although the number of editorial materials is slightly higher than the number of articles, their citation rate is far lower than that of the latter, demonstrating that it would be difficult to drastically improve a journal's IF by increasing the number of editorial materials only. Nevertheless, there could well be special cases for individual journals.

Through a structural analysis of the highly cited papers, authors, and institutions in *Nature*, we found that the magnitude of *Nature*'s IF for 2013 is made up of the combined contributions from many highly cited papers, authors, and institutions, and that the highly cited papers, authors, and institutions are distributed relatively evenly. In other words, *Nature* is different from other journals in which few highly cited papers make a disproportionate contribution to the total number of citations (Liu 2014b), such as the *Cancer Journal for Clinicians*. This journal's IF for 2012 is 153.459; this high IF is derived mainly from the contributions of two papers written by A. Jemal (Jemal et al. 2010; Jemal et al. 2011), "Cancer statistics in 2010" and "Cancer statistics globally," in which the combined contribution rate is 70.9 percent.

Similarly, different countries and regions made entirely different contributions to *Nature*'s IF for 2013; countries making the greatest contributions are mainly distributed in Europe, Asia, and America. The USA and England made the greatest contribution to *Nature*'s IF, and the USA's contribution is well ahead of other countries. The differences in contributions to IF from different countries and regions remind us that we should pay close attention to the balanced development of global scientific research to promote academic exchange between different countries and regions.

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