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Publication details:
Scientometrics
v. 82
Chapter No. 3
pp. 613-626
1588-2861 (ISSN)

Publication Date:
2010

Publisher DOI:
http://dx.doi.org/10.1007/s11192-010-0175-y

Journal Impact Factors for evaluating scientific performance: use of *h-like* indicators

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Abstract This article introduces the Impact Factor squared or IF²-index, an h-like indicator of research performance. This indicator reflects the degree to which large entities such as countries and/or their states participate in top-level research in a field or subfield. The IF²-index uses the Journal Impact Factor (JIF) of research publications instead of the number of citations. This concept is applied to other h-type indexes and their results compared to the IF²-index. These JIF-based indexes are then used to assess the overall performance of cancer research in Australia and its states over 8 years from 1999 to 2006. The IF²-index has three advantages when evaluating larger research units: firstly, it provides a stable value that does not change over time, reflecting the degree to which a research unit participated in top-level research in a given year; secondly, it can be calculated closely approximating the publication date of yearly datasets; and finally, it provides an additional dimension when a full article-based citation analysis is not feasible. As the index reflects the degree of participation in top-level research it may favor larger units when units of different sizes are compared.

Keywords Journal Impact Factor • IF²-index • Research evaluation • Australia • Cancer research • h-Index • h-Type indexes • h-Like indexes • Scientometrics

Introduction

Evaluating research performance is generally constrained by time and money and often accompanied by a limited understanding of bibliometric methods by authorities and audiences requiring assessment of research areas, institutions or geographical regions. In some cases a brief approximation of the current research standing is preferred over a detailed analysis. In this paper we suggest a new measure that can be efficiently calculated and which is intended to add additional information about the level of research quality when comparing larger research units. This indicator has the advantage that it can be efficiently obtained and that it reflects the degree of participation in top-level research in one single measurement. It is not intended to replace citation analysis for assessing the impact of research on the academic community, but rather as an indicator which can give insight into the degree of participation in top-level research in cases when full citation analysis is not feasible.

Since the introduction of the *h*-index (Hirsch 2005) a number of studies have shown the practical use of this measure to evaluate scientists within specific disciplines (e.g., Cronin and Meho 2006; Oppenheim 2007). Consequently it was rapidly incorporated into e-resources such as the Web of Science and Scopus to measure an author's comparative 'standing' in a particular research community. Likewise, the informetric community quickly adapted the *h*-index and started investigating its shortcomings (Burrell 2007a; Costas and Bordons 2007) and properties (Bornmann and Daniel 2007; Bornmann et al. 2008a; Burrell 2007b; Egghe 2007; Vanclay 2007) as well as developing various modifications and improvements to the indicator, subsumed as *h-type* or Hirsch-type indicators (Rousseau 2008), such as the *g*-index (Egghe 2006), *h(2)*-index (Kosmulski 2006), *A*-index (Jin 2006 cited by Rousseau 2006), *R*-index (Jin et al. 2007) and the *m*-index

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(Bornmann et al. 2008b). The developments and applications of these new or variant indicators were quickly followed by studies comparing one or more of them to the *h*-index (e.g., Bornmann et al. 2008b; Burrell 2009; Costas and Bordons 2008; Schreiber 2008) and to existing standard informetric indicators and peer judgment (e.g., Van Raan 2006). Recently Gla¨nzel (2008) has alerted the informetric community to new applications of rank-frequency and extreme-value (or tail properties of Pareto-type distributions) statistics related to the *h*-index. Furthermore, the *h*-index, initially intended for the assessment of individual academics, has been extended from micro-level evaluation of individuals to macro-level evaluation of journals (Braun et al. 2005, 2006; Schubert and Glänzel 2007; Vanclay 2008), research groups (Van Raan 2006) and institutions (Arencibia-Jorge et al. 2008; Molinari and Molinari 2008; Pires da Luz et al. 2008). A recent application of the *h*-index to an even further micro-level was made by Schubert (2009) to assess single highly cited publications. Additionally, novel *h-type* indexes were introduced by Schubert et al. (2009) to characterize networks: the 'degree *h*-index' which measures the 'influential weight' of a network based on its size and density. Egghe (2008) reports on the influence of two types of merging of information production processes (IPPs) on *h-type* indexes. Finally, we like to alert the readers of Egghe's (2010) forthcoming review paper on the *h*-index in ARIST (*Annual Review of Information Science and Technology*).

In this paper we introduce the term '*h-like*' index in order to distinguish between Hirsch-type indexes based on citations, often referred to as h-type indexes and indexes using the same rationale as *h-type* indexes but which are not based on citations, but rather on Journal Impact Factors (JIFs).

Simply described, the *h*-index brings together two dimensions of academic performance in one measure. These dimensions are productivity (number of publications) and visibility (citations to those publications), whereby an academic's *h*-index is defined as the lowest number both dimensions share. For example, an *h*-index of 10 means that an academic has published 10 publications each receiving at least 10 citations (Hirsch 2005). Thus the *h*-index is insensitive to excessive productivity of publications receiving few or no citations and to authors having published comparatively few articles but receiving good visibility through numerous citations.

However, one major drawback the *h*-index shares with all citation-based research indicators is the requirement of elapsed time, often years, for citations to accumulate. This time-lag between publication and citation, therefore hinders the use of *h-type* indexes for the assessment of recent publications. This is especially critical for research funding institutions (like the NSW Cancer Institute) as they have to keep track of the outcome of their research funding and adjust their policies and funding strategies in a timely manner. This article will introduce an alternative to *h-type* indexes for evaluation, seeking to overcome this shortcoming of citation-based analysis by using the journal impact factor (JIF) of the journals in which the research has been published. The advantage of using JIFs is that they are available in a timely manner; they are published approximately six months after the publication year of an article and in numerous cases they can be anticipated during the publication year with reasonable accuracy (Ketcham and Crawford 2008).

JIFs are good predictors of research quality when looking at large numbers of publications. However, using JIFs for evaluating individual academics is controversial because of the often extremely skewed distribution of citations to articles within journals (see, for example, Opthof 1997). Nevertheless, it has been shown that JIFs can be used for evaluation when the number of articles exceeds the critical threshold of approximately 100 publications within a timeframe of 2 years (Opthof 1997; Lehrl 1999; Kaltenborn and Kuhn 2004). Another common argument against using the JIF for research evaluation is the notion that not all top-level research is always published in high Impact Factor (IF) journals and conversely not all articles in high IF journals are always top-level research. Even though, this can be the situation for individual publications; empirical evidence exists for correlations between IFs and methodological quality (Lee et al. 2002); between IFs and peer assessment of journal quality (Saha et al. 2003; Yue et al. 2007); and recently, between the *h*-index and JIFs in the ranking of journals (Vanclay 2008). Therefore, we argue that there is a positive link between journals with high IFs and the quality of research, especially when looking at larger sets of 100 or more publications. Despite the negative aspects of JIFs, recent debates are directed more towards the accuracy and transparency of Thomson Reuters citation data and not necessarily towards the JIF itself (Rossner et al. 2007, 2008; Ketcham and Crawford 2008; Pringle 2008).

In this paper we show how JIFs of cancer-related publications can be used to compare and contrast the extent of participation in top-level cancer research among the Australian states—here defined to include

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states and territories. It is based on data gathered for a project commissioned by the NSW Cancer Institute assessing the quantity and quality of cancer-related research of Australia and of each state over an 8-year period from 1999 to 2006 (Wilson et al. 2007; Welberry et al. 2008). It shows how JIFs can be used similarly to citation-based *h-type* indexes for evaluating the performance of research units producing more than 50 publications annually. It demonstrates that simply applying *h-type* indexes by replacing citations with the impact factors (IFs) of the journals of those publications does not provide satisfactory results. An alternative way of using IFs is introduced, allowing the use of IFs for timely *h-like* comparison of Australian cancer-related research among institutions aggregated by states.

Method

Keywords/keyphrases were used to retrieve all cancer-related publications from the Science and Social Science Citation Indexes of Thomson Reuters containing at least one author with an Australian affiliation published between the years 1999 and 2006.[1] Using the corporate source/address field allowed the allocation of all publications to each of the eight Australian states; publications with multiple authors were allocated to more than one state, but not more than once to the same state. The ISSN and year of each journal publication were then used to obtain the appropriate JIFs for each publication from the Journal Citation Reports of Thomson Reuters. After assigning appropriate JIFs to each publication, the publications were ranked in decreasing order of their IFs for each year and each state. Using this ranked list of publications, several h-like indicators were calculated. These indicators are referred to as *h-like* for they are not based on citations but rather on JIFs. In contrast *h-type* indexes refer to all citation-based variants of the *h*-index including itself. To see how the results for different *h-type* indexes differ when applied to JIFs we chose the *h*-index (Hirsch 2005) and five other *h-type* indexes for comparison: Egghe's (2006) *g*-index, Kosmulski's (2006) *h(2)* index, the *A*-index (Jin 2006 cited by Rousseau, 2006), the *R*-index (Jin et al. 2007) and the *m*-index (Bornmann et al. 2008).

Results

Overall, Australian authors contributed a total of 17,917 unique cancer-related publications over 8 years from 1999 to 2006 and JIFs were available to well over 90% (16,411) of all cancer-related publications for all states. With the exception of Tasmania (TAS) and the Northern Territory (NT), six states meet the requisite of more than 100 publications in 2 years (Table 1). Hence, only results from the annual publications (1999 to 2006) of six states (NSW, VIC, QLD, WA, SA and ACT) were analyzed in this study. Also, as the comparison of units with different levels of research productivity using the same indicator can be affected by the level of productivity, we like to highlight two-pairs of states performing at similar levels; NSW-VIC and WA-SA (Table 1).

For each year all publications for each state (and overall for Australia) were ranked in decreasing order of their JIFs. Figure 1 shows the rank-ordered distribution of cancerrelated publications from Australia for the years 1999 (n = 1,668) and 2006 (n = 2,594). It is clear that the distribution of JIFs over publications follows an extremely skewed distribution with less than 20% published in journals with higher IFs ([6) and the majority (over 80%) appearing in journals with lower IFs (B6). This general shape of the distribution is similar to the distribution of citations to an academic's work used as the basis for calculating *h-type* indexes.

Using this distribution for each year and for six states, the values for all six *h-like* indexes were calculated. The results in Table 2 show a clear trend for the increasing performance of top-level cancer research in Australia over the 8-year period. This is a clear improvement over the results in earlier studies using mean impact factors (IFs) to compare the quality of cancer research over the years and among the Australian states (Wilson 2005; Wilson and Pittman 2000; Welberry et al. 2008). One example of insufficient discrimination within a state occurred for NSW which had the same mean IF (3.40) in 2000 and 2001;

1 For a detailed description of the methodology, see Wilson et al. (2007), Welberry et al. (2008) or contact the authors directly for additional information.

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Table 1 Number of cancer-related publications with JIFs allocated over Australian states: 1999-2006

	NSW	VIC	QLD	SA	WA	ACT	TAS	NT	Australia
1999	640	548	290	197	179	68	21	11	1668
2000	648	619	308	199	178	89	30	7	1769
2001	664	602	330	182	212	70	29	3	1751
2002	698	673	373	187	196	64	26	7	1880
2003	742	707	360	233	222	79	25	13	1943
2004	898	867	418	252	281	106	31	13	2340
2005	918	968	486	261	274	102	24	10	2466
2006	1019	1045	499	286	306	112	34	9	2594
8-yr period	6227	6029	3064	1797	1848	690	220	73	16411

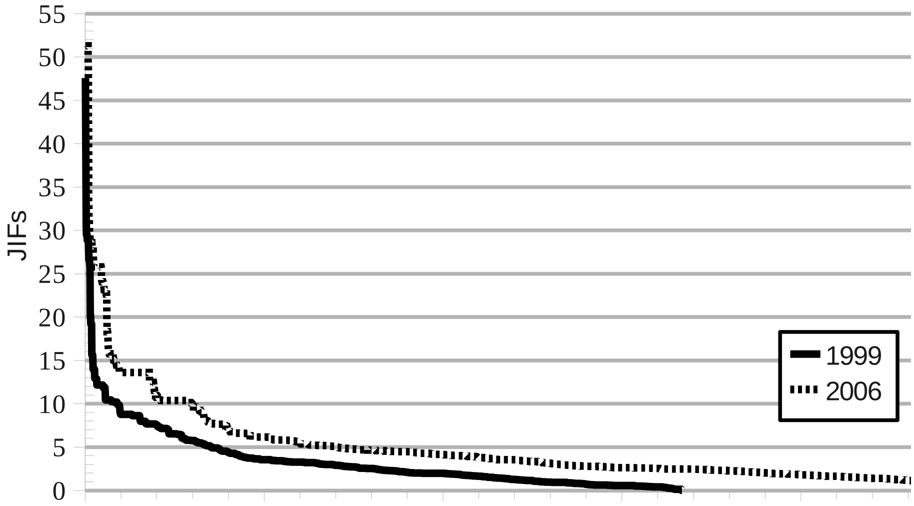

Fig. 1 Distribution of JIFs of Australian cancer-related publications for 1999 and 2006

another example between states occurred for QLD and SA when both had the same mean IF(3.45) in 2000 (Welberry et al. 2008, p. 71). However, when the results in Table 2 are plotted in Fig. 2, each of the six *h-like* indicator presents a slightly different picture. Clearly the most erratic pattern can be observed for the *m-like* index using the median IF of the *h-core* for each year. Also striking is the similarity of the graphs for the *g-like* index and the *R-like* index with the 'characteristic lines' (i.e., the general shape of the distribution over time) showing very similar patterns in both cases; though the values for the *R-like* index were generally lower than those for the *g-like* index. This is especially interesting, as the *R-like* index is based on the *h-core* encompassing approximately just two-thirds of the publications included in the *g-like* index.

When comparing the research performance of each Australian state it becomes apparent that two states are leading in the output of top-level cancer research: New South Wales (NSW) and Victoria (VIC), the two largest and most comparable states in terms of publication output. However, comparing the six different *h-like* indicators using JIFs suggests that they lack the power to discriminate between the different states (or time-periods). This is especially true for the *h(2)-like* index where the results for all states are very close to each other.

Looking back at the distribution of JIFs over publications (Fig. 1), reasons for this result become apparent. In contrast to the usually perceived distribution pattern of citations to an academic's work, the distribution of IFs over cancer-related publications is much more skewed. There are two reasons for this: Firstly, the highest IF for publications (e.g., 51.296 for a 2006 cancer-related paper in *The New England Journal of Medicine* co-authored by researchers in Australia, see Fig. 1) is considerably lower than the number of citations observed in the *Web of Science* for a highly cited (219 as of November 2008) paper coauthored by researchers in the Australian state ofWAin the same journal (Geyer et al. 2006).

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Table 2 Values of 'h' Index; 'g' Index; 'h(2)' Index; 'A' Index; 'R' Index and 'm' Index for six Australian states (NSW, VIC, QLD, WA, SA and ACT): 1999 to 2006.

		1999	2000	2001	2002	2003	2004	2005	2006
NSW	'*h*' Index*	12.0	12.2	13.3	15.0	14.3	17.0	15.7	15.3
	'*g*' Index	16	19	14	20	21	23	22	26
	'*h(2)*' Index*	4.0	5.1	3.9	5.2	5.0	5.7	4.9	6.0
	'A' Index[1]	18.2	23.8	14.1	22.6	24.8	28.0	26.5	36.1
	'm' Index[1]	13.5	20.5	14.1	21.6	18.3	22.8	23.9	27.6
	'R' Index[1]	14.8	16.9	13.5	18.4	18.6	21.8	19.9	23.3
VIC	'*h*' Index*	14.0	15.2	14.2	15.8	16.0	16.0	23.0	22.0
	'*g*' Index	20	20	18	22	21	24	28	27
	'*h(2)*' Index*	5.2	5.0	4.8	5.3	5.0	5.7	5.6	5.4
	'A' Index[1]	24.9	23.0	20.5	25.1	23.2	30.6	30.5	29.8
	'm' Index[1]	26.6	23.9	18.1	26.7	17.8	30.1	28.9	26.7
	'R' Index[1]	18.0	18.6	16.9	19.4	19.2	22.1	26.5	25.6
QLD	'*h*' Index*	11.0	10.4	10.9	13.4	11.6	12.6	12.4	15.0
	'*g*' Index	14	15	14	17	17	16	20	20
	'*h(2)*' Index*	3.6	3.8	3.8	5.0	4.3	4.0	4.9	5.1
	'A' Index[1]	15.1	18.0	17.0	19.7	20.7	18.8	25.8	23.8
	'm' Index[1]	12.9	14.2	14.2	15.4	18.3	14.1	23.9	24.2
	'R' Index[1]	12.9	13.4	13.1	16.0	15.1	15.0	17.6	18.9
WA	'*h*' Index*	8.8	10.2	13.0	10.0	11.0	11.6	13.0	13.6
	'*g*' Index	13	14	16	12	17	17	21	22
	'*h(2)*' Index*	3.7	3.9	4.1	3.7	4.3	4.7	5.0	5.0
	'A' Index[1]	15.7	17.1	17.3	12.9	22.3	22.5	27.0	28.7
	'm' Index[1]	12.9	12.4	13.3	13.2	18.3	14.6	23.9	15.9
	'R' Index[1]	11.2	13.1	15.0	11.4	15.7	15.7	18.7	19.3
SA	'*h*' Index*	10.2	10.0	10.0	9.8	10.1	9.8	11.8	12.5
	'*g*' Index	13	12	13	13	14	11	16	17
	'*h(2)*' Index*	3.5	3.5	3.6	3.3	3.7	3.5	3.7	3.9
	'A' Index[1]	14.8	13.0	15.5	15.1	16.8	11.0	17.9	20.7
	'm' Index[1]	12.2	12.2	13.0	10.7	13.8	10.4	12.4	13.6
	'R' Index[1]	12.2	11.4	12.4	11.7	12.9	12.0	14.0	15.8
ACT	'*h*' Index*	7.1	7.4	7.3	6.7	9.6	9.0	9.6	10.4
	'*g*' Index	9	10	10	9	13	12	12	13
	'*h(2)*' Index*	2.0	3.2	3.6	3.3	3.9	3.4	3.4	3.9
	'A' Index[1]	11.1	13.1	13.4	12.2	15.6	14.6	13.5	14.7
	'm' Index[1]	7.7	10.4	12.9	12.6	15.3	10.7	11.8	13.6
	'R' Index[1]	8.8	9.6	9.7	8.6	11.8	11.5	10.9	12.1

* Values for the *h*-index and *h(2)*-index can be non-natural numbers, as the JIF can be a real number. Therefore if the JIF is greater than the number of publications the JIF will be used as a limit. [1]The *A*-index; *m*-index; and *R*-index are based on the *h-core*; that is, they only use the top h publications.

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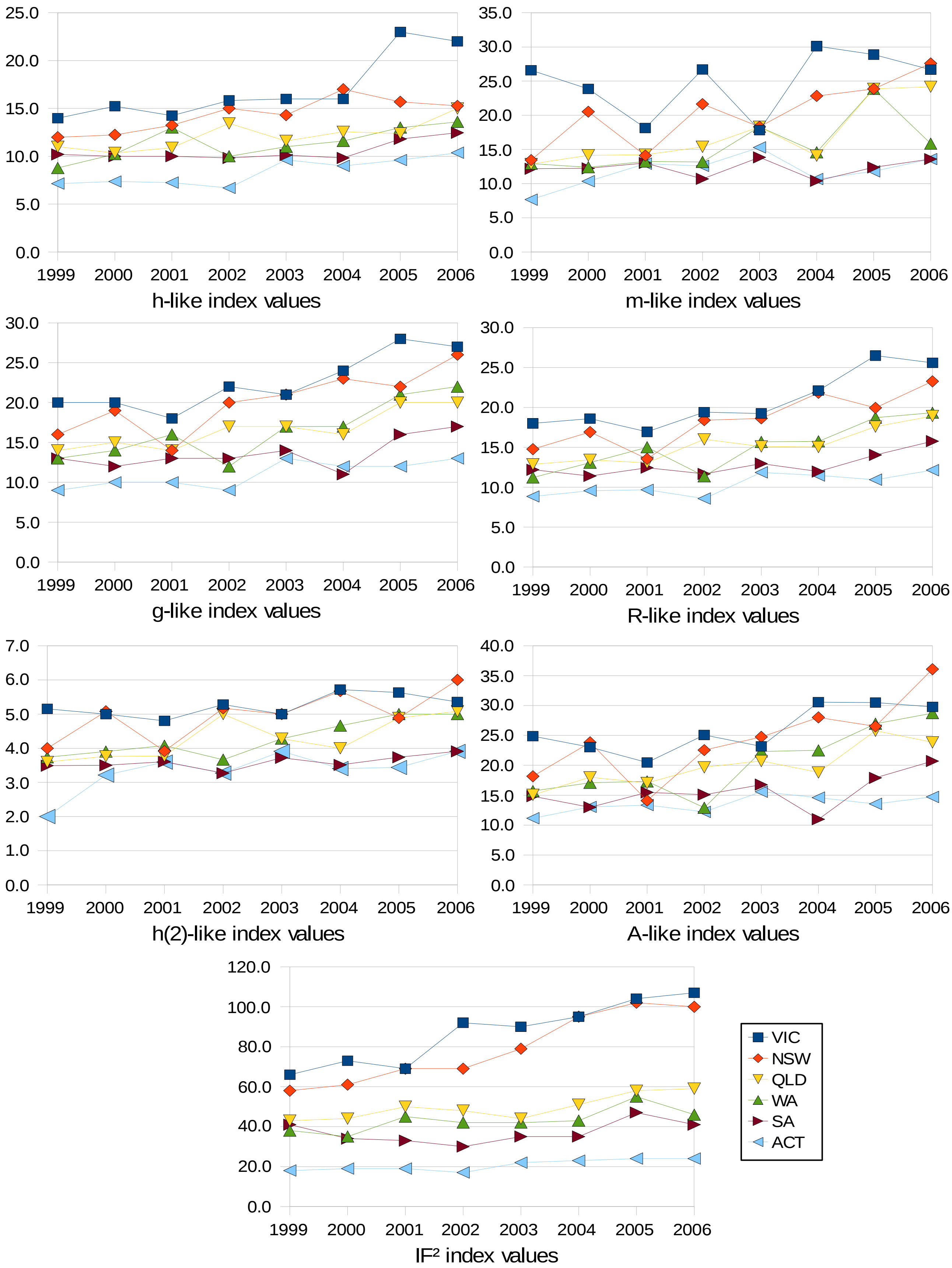

Fig. 2 Values for six *h-like* indexes and the IF²-index for NSW, VIC, QLD, WA, SA and ACT: 1999 to 2006

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Table 3 IF²-Index for the Australian States: NSW, VIC, QLD, WA, SA, ACT for the Years 1999 to 2006.

	1999	2000	2001	2002	2003	2004	2005	2006
VIC	66	73	69	92	90	95	104	107
NSW	58	61	69	69	79	95	102	100
QLD	43	44	50	48	44	51	58	59
WA	38	35	45	42	42	43	55	46
SA	41	34	33	30	35	35	47	41
ACT	18	19	19	17	22	23	24	24

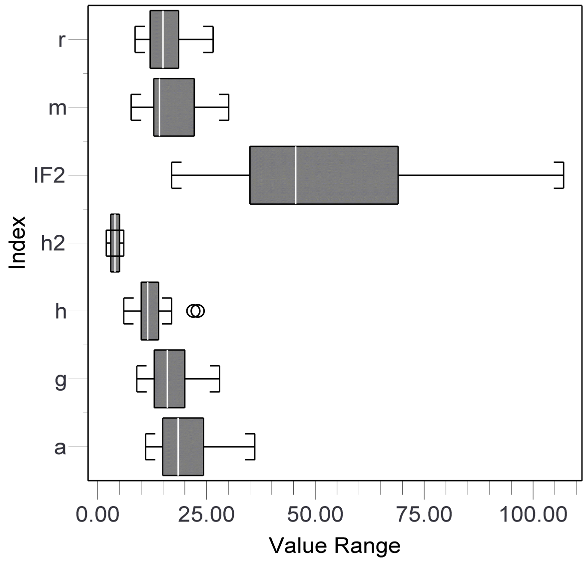

Fig. 3 Boxplot showing the range of values for all *h-like* indexes and the IF²-index

The calculation of JIFs is based on a citation window of 2 years and as this time limit does not apply when looking at citations to an academic's research output; articles usually have more time to accrue citations. For example, a 2002 cancer-related paper in *Nature* co-authored by researchers in Australia was cited 1,417 times as of November 2008 (Davies et al. 2002). This phenomenon is also supported by the h-indexes for journals which are usually much higher than journal IFs (Braun et al. 2006). The second reason relates to the sheer number of publications. In 1999 Australia produced approximately 1,700 cancer-related publications and in 2006 nearly 2,600 (see Table 1). This amount of publications is clearly much more than (most) academics can produce over their professional careers.

To overcome this limitation we propose the IF²-index which adjusts the values of the JIFs by squaring the IFs before applying them to the publications. This results in a distribution where the dimensions, research productivity and research quality, are somewhat balanced. Similar to the definition of the *h*-index introduced earlier, the IF²-index is defined as the lowest number the two dimensions of productivity and quality share, where the quality dimension is determined by squaring a publication's IF. For example, an IF² value of 58 means that a research unit has produced 58 publications with an IF of $\sqrt{58} \approx 7.616$ or more. The results for the IF²-index for the six Australian states are listed in Table 3 and plotted for comparison to the six *h-like* indexes in Fig. 2. It is apparent that the IF²-index would seem to provide the greatest discriminatory capability. The 'characteristic lines' for all states have fewer intersections, thus providing a clearer picture of the degree to which top-level research is undertaken by the Australian states. Furthermore, the Australian states show a clear grouping: The two largest states (in terms of overall population and publication productivity) VIC and NSW are clearly ahead of QLD, WA and SA, which are in turn well ahead of ACT. Using the IF²-index also helps to distinguish between states with comparable levels of productivity. In the case of NSW and VIC it becomes apparent that even though VIC had a slightly lower research output over the first 6 years (see Table 1) it is participating in top-level research on an equal or better level then NSW

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over the complete 8 years (see Table 3). A comparison of the number of cancerrelated publications from SA and WA for each year shows a continuous jostling for the lead position each year (Table 1). However, looking at the IF²-index it is apparent that since 2000 WA constantly produced more top-level research publications than SA (see Table 3).

We investigated further the IF²-index's discriminatory capability in contrast to the other six *h-like* indexes. A boxplot chart comparing the value ranges of all *h-like* indexes was compiled. Figure 3 displays the value ranges for all six *h-like* indexes and the IF²-index for the six Australian states for the 8-year period (1999–2006). The earlier notion of the *h(2)-like* index being least discriminatory is confirmed. As all value ranges are based on the same set of publications (for six Australian states over 8 years), it is clear that the values derived using the IF²-index provides the greatest range, thus giving the best discriminatory capability to compare the degree to which Australian states participate in top-level cancer research.

Discussion

Similar to the *h-like* index, the *g-like* index and the *h(2)-like* index the IF²-index represents real existing units of measurement. That is, the common element in all four indexes is the existence of real numbers of journal publications, thus fulfilling the extent or degree of visibility, quality or impact criterion.[2] In contrast, the m-like, *A-like* and the *R-like* index are describing the shape of the content of the *h-core*; this is arguably a more abstract concept that is not represented by real existing physical units. In the case of our Australian cancer research data, the *m-like* index displayed particularly 'erratic' yearly movements (especially for the top-state, Victoria) which may be attributed to the yearly changes in the content of its *h-core*.

By describing the *h-like*, *g-like*, *h(2)-like* and IF²-indexes as numbers of publications, they can be interpreted as dividing a set of publications produced by a research unit into two subsets. One subset consists of the publications fulfilling the criterion of having an index value for each publication equal to or greater than the value of the according index, while the other subset consists of publications not fulfilling the criterion. For example, if the *h-like* index is 17, each publication published in a journal with an IF of ≥17 fulfills the criterion. As the criterion changes according to the productivity and the achieved visibility of a research unit, *h-type* indexes can be described as a dynamically scaled criterion dividing the publications produced by that research unit. In the case of our Australian study, for every year and for each state all cancer-related publications are defined as toplevel cancer research for that state if it fulfills the criterion for that year. As the criterion is dynamically changing according to the research unit's performance, the necessary number of publications and the necessary value of the IFs change accordingly. Therefore, one publication with a certain IF (e.g., 4.567) could be considered top-level cancer research in one state while not fulfilling the top-level research criterion in another state as the necessary criterion for this other state is set at a higher level (above 4.567). This underlines the notion that the IF²-index is an indicator *reflecting the degree to which top-level research is undertaken by a specific research unit*; a higher value for the IF²-index denotes a higher level of participation in top-level research. If a unit produces research that meets the editorial and peer review criteria for publication in high IF journals but does not produce many publications, it will not be able to achieve a high IF²-index as it does not show a high degree of participation in top-level research. Accordingly, if a unit produces many publications but only a few of them meet the criteria for publication in high IF journals, it will not be able to achieve a high IF²-index as it does not show a high degree of participation in top-level research either.

To confirm the dynamics of the criterion and to confirm that in all cases just top-level research was considered, we give the lowest IF for the *h-like* index, *g-like* index and the IF²-index fulfilling each criterion in Table 4. This means all publications in the data sets have an IF equal to or higher than the values given in Table 4. It is clear that for all three indexes, nearly all publications could be considered as appearing in top IF

2 For our purpose we decided to allow real numbers for the h-like index and the h(2)-like index as they reflect the fact that IFs can be real numbers. Arguably fractions of publications do not exist and therefore the conservative criterion for both indexes had to be used to determine the number of publications. This is always the natural number before the decimal point; e.g., for the h-like index, a value of 17.808 represents 17 publications as the 18th publication does not fulfill the criterion of having an IF of 18 or more.

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journals with an IF > 6. The exception here is the IF²-index for the ACT that did not reach the same degree of participation in top-level cancer research as the other Australian states. The actual ranges for the lowest IFs considered fulfilling the criterion are:

h-like index	from 7.258 (ACT in 2001) to 23.494 (VIC in 2005);
g-like index	from 6.696 (ACT in 2002) to 18.725 (VIC in 2005);
IF²-index	from 4.349 (ACT in 1999) to 10.370 (VIC in 2006)

The effect of dividing a set of publications into two halves can be seen as a strength of the proposed IF²-index. This stems from the fact that journal rankings based on JIFs are sometimes criticized for not being accurate; that is, JIFs are reported to three decimal places but this degree of accuracy is deceptive as it was merely introduced by Garfield as a means of avoiding too many ties in the journal ranking (Bensman 2007, 123f). However, we would like to point out that, although publications had to be ranked according to the JIF's of the publishing journals in order to calculate the index values, the IF²-index does not differentiate among the journals fulfilling the necessary criterion. That is, differences in the IFs of publications fulfilling the criterion are ignored. If, for example, publications in 10 different journals fulfill the criterion of top-level research, it is immaterial how these 10 journals rank relative to each other when IFs differ only slightly (say, 0.001). All publications in these journals are considered top-level research. This apparent weakness of the original h-index becomes a strength of the IF²-index as it does not state that a research paper in journal A with the IF '*x*' is 'better' than a research paper in journal B with the IF '*y*'. The two journal papers are seen 'equally' as long as both journals fulfill the criterion of top-level research for the research unit being assessed.

However, there is one shortcoming of the proposed IF²-index: JIF-based assessment cannot satisfactorily reflect all aspects of cancer-related research. For example, outstanding work on the social effects of cancer is likely to appear in social science journals which on average have much lower JIFs than prestigious clinical medicine journals.

Given the recent criticism related to the accuracy of citation data fromThomson Reuters as applied to the calculations of JIFs, we like to state that even if different data provided (slightly) different results for some

Table 4 Lowest Journal Impact Factors (JIFs) of publications meeting the criterion for the*h-like* index, *g-like* index and *IF*²-Index: six states from 1999 to 2006

State			1999	2000	2001	2002	2003	2004	2005	2006
NSW	'h' core	Lowest JIF	12.182	14.159	13.251	15.397	17.324	20.233	19.211	23.175
	'g' core	Lowest JIF	10.426	10.232	13.251	14.500	12.718	13.856	15.171	13.598
	IF² core	Lowest JIF	7.666	8.018	8.530	8.726	8.894	9.782	10.131	10.000
VIC	'h' core	Lowest JIF	13.973	15.236	14.240	15.837	16.016	16.120	23.494	22.672
	'g' core	Lowest JIF	12.182	14.954	14.240	15.397	14.307	14.204	18.725	16.710
	IF² core	Lowest JIF	8.281	8.773	8.530	9.631	9.503	9.782	10.231	10.370
QLD	'h' core	Lowest JIF	11.435	10.789	13.020	13.625	11.910	13.856	12.649	15.271
	'g' core	Lowest JIF	10.426	10.351	10.542	10.700	11.602	10.452	11.810	13.598
	IF² core	Lowest JIF	7.145	6.834	7.103	6.954	6.702	7.260	7.616	7.751
SA	'h' core	Lowest JIF	10.260	10.789	10.542	9.868	10.120	9.835	11.810	12.457
	'g' core	Lowest JIF	8.955	9.048	9.273	9.631	10.120	9.782	11.810	10.370
	IF² core	Lowest JIF	6.517	5.877	5.893	5.480	6.125	5.973	6.872	6.473
WA	'h' core	Lowest JIF	8.782	10.351	13.020	10.649	15.302	11.602	15.171	13.598
	'g' core	Lowest JIF	8.782	9.666	10.542	9.868	10.120	10.452	11.810	11.808
	IF² core	Lowest JIF	6.403	5.996	6.737	6.565	6.702	6.601	7.526	7.371
ACT	'h' core	Lowest JIF	7.666	7.368	7.258	8.318	9.635	9.835	9.608	10.446
	'g' core	Lowest JIF	7.145	6.834	6.737	6.696	7.397	7.690	14.131	8.099
	IF² core	Lowest JIF	4.349	4.643	4.476	4.566	4.820	5.076	5.854	5.029

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journals or journal rankings, this would not affect the method introduced here. In contrast, we welcome discussion on impact factors if they lead to more transparent and more widely acceptable results for the JIFs used in the scientific community.

An advantage of all measures introduced here is the provision of stable figures over a fixed timeframe for research performance that does not depend on years for research papers to accrue 'prestige' through citations. Such measures provide comparison of the performance in prolific research areas (e.g., cancer) by giving a single measure for the performance of top-level research among, for example, geographical regions within a country or between/among countries.

Conclusion

This paper introduced a 'new' measure similar to the *h*-index, one based on the JIFs of papers rather than on the numbers of citations to them. The informetric measure introduced in this paper can provide guidance for future analysis and evaluation of research performance in all disciplines where research is published in journals with high IFs. It may assist in the assessment of the quality of research output from larger academic units in a timely manner. It could prove useful in evaluating and comparing research performance of large research units such as laboratories, institutions, states/provinces within countries, countries or geographical regions (e.g., the European Union). Our study shows that JIFs can be used to establish a measure similar to the *h*-index which provides timely and robust comparison of research performance at the macro-level. Using an *h-like* measure based on the square of the journal impact factor (IF^2) can overcome the contrast between the numeric ranges of JIFs (lower) to that of citations (higher). This 'new' measure allows finer granularity when comparing large research units and better comparison of (or discrimination among) disciplines than simply applying the concept of *h-type* indexes to JIFs.

Future research should proceed in several directions. Firstly, the usage of the concept of the IF^2-index should be confirmed by applications in other fields of medicine. Secondly, the IF^2-index should be investigated to see if it can be scaled from national to cross-country comparisons. And finally, the relationship of the IF^2-index to citation-based assessment of research quality should be investigated. Comparing results using actual numbers of citations received by different research units to an IF^2-index based results for the same research units could establish if both approaches provide comparable results and if using actual numbers of citations may provide yet another (and perhaps more accurate) comparative measure (Seglen 1994).

We would also like to acknowledge that JIF-based assessment of cancer-related publications should by no means substitute for qualitative analysis of the content of papers based on reading and judgment through expert panels. Instead we propose this indicator as a supplement for a quick assessment of the degree to which research units participate in top-level research in a field when no detailed expert-based assessment or citation-based analysis is possible. The proposed indicator therefore has several advantages over citationbased analysis (or judgement made by expert panels): Firstly, assessment based on the IF^2- index can be undertaken more efficiently (and cost-effectively) for large research units. Secondly, it can be undertaken much closer to the publication date than citation-based analysis thus allowing timely analysis when necessary. And lastly it provides stable results that do not change over time.

Acknowledgements The authors acknowledge with thanks the support of the John Metcalfe Memorial Fund and helpful comments from the anonymous reviewers.

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