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Evaluating the research performance of the Greek medical schools using bibliometrics

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Abstract Quality in Higher Education Institutions is the subject of several debates in the academic community in a worldwide basis and various efforts are made towards identifying ways to quantify it. In this respect, the use of bibliometrics gains significant ground as an effective tool for the evaluation of universities' research output. In the present study, the research performance of the seven Greek medical schools is assessed by means of widely accepted and advanced bibliometric indices, such as total and average publications and citations, average and median h- and g-index with and without self-citations for all the 1,803 academics, while statistical analysis of the data was also performed in order to compare the observed differences in the mean values of the calculated indices. Considerable effort was exerted to overcome all inherent limitations of a bibliometric analysis through a meticulous data collection. This large-scale work was conducted both in school and academic rank level leading to interesting results concerning the scientific activity of the medical schools studied as units and of the various academic ranks separately, which can be partially justified with geographic and socioeconomic criteria. In general, bibliometrics demonstrate statistically significant difference in favour of Crete University medical school, while it was also found that self-citations have only marginal effect on the individual's research profile and the average indices. Finally, the useful findings of the

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present study render the methodology adopted of high viability for assessing the research performance of Higher Education Institutions even in a broader context.

Keywords Research evaluation · Bibliometrics · h-index · g-index · Medical school · Self-citations · ANOVA

Introduction: research aims

University is regarded as the most important social space for the promotion of ideas and intellect (Garcia-Aracil and Palomares-Montero 2010) and, as such, rigorous and internationally accepted criteria and procedures should be established to ensure its quality. However, quality is a general term and one of many concepts in the social sciences that is extremely difficult to define and, as Lagrosen et al. (2004) further note, when it refers to higher education it becomes even more difficult to define than in most other sectors, since it should be first determined what dimensions constitute quality in higher education.

Despite the fact that in order to assure quality in higher education institutions several variables must be taken into account, it is generally accepted that among the most important factors that quality in universities encompasses are infrastructures, educational process and the research performance/productivity of the faculty. In order to assess the quality of a university based on at least the above factors, prerequisite is to agree internationally on terms such as levels, standards, effectiveness and efficiency (Frazer 1994) and to somehow quantify them.

In this respect, the first two quality indicators is hard to quantify, while for the latter, namely the research performance of the faculty, several ways have been proposed the most prominent of which is the use of bibliometrics. The internet proliferation has contributed to a great extent to this direction, since published scientific material, such as publications in journals and/or conference presentations or other scientific achievements (e.g. patents) of the academic staff of all universities, can easily be accessed in the web. In the same time, it is worth mentioning that several databases have also been created which collect a significant percentage of the published material and categorize it by researcher, affiliation, scientific area etc., allowing the extraction of useful information for the evaluation of the research output of an institution and/or its members separately.

Bibliometric indices are gaining ground nowadays, since they offer an unbiased and relatively fair way to compare the scientific outcome between universities and/or researchers of the same scientific discipline in the same or different countries, despite their potential drawbacks (Zachos 1991; Bach et al. 2011). In addition, there is a general trend to use bibliometrics as tools for monitoring scientific development, funding purposes and the evaluation of individuals (Aksnes 2009).

As Lazaridis (2010) remarks, although ranking a university may be a task hard to accomplish due to its heterogeneity, since it may contain excellent as well as mediocre departments, the evaluation of individual departments is worth trying. In this respect, only a handful studies have been conducted regarding the evaluation of European university departments using bibliometrics (e.g. Sypsa et al. 2008; Sypsa and Hatzakis 2009), especially in Greece.

An early attempt to compare two Greek Mathematics departments using bibliometric indices was published in 1991 (Zachos 1991). Much later, Katsaros et al. (2008) analysed the performance of seventeen Greek Departments of Computer Science/Engineering using a series of bibliometric indices investigating 552 academics using Google Scholar and

Publish or Perish software. In the same respect, Lazaridis (2010) used the h-index calculated by the Web of Science scientific database to evaluate faculties in Greek Chemistry, Chemical Engineering, Materials Science and Physics departments. Similarly, Vaxevanidis et al. (2011) used various bibliometric indices to assess the research performance of six (6) Greek University departments of the same discipline (Mechanical Engineering), while the Scopus database was employed for the retrieval of the research outputs of all faculty members. Only recently, Altanopoulou et al. (2012) using the scientific record of 3,354 academics as retrieved by means of Google Scholar evaluated 93 major Greek University departments of various disciplines.

Towards this respect, in the present work the research output of the seven (7) Greek university medical schools which host a total of 1,803 academic staff members is studied by means of various bibliometric indices, as described below. Such a study is of great interest since academics of medical schools constitute more than 15 % of all academics in the higher education institutes in Greece. In addition, the role of academics in medical schools is extensive and much differentiated from that of academics of other scientific disciplines, since they are in parallel involved in research, teaching and healthcare providing patient treatment in university hospitals.

The scope of the present paper is twofold. First, to evaluate the efficiency of researchers of the same discipline (i.e., medicine) and record for the first time, to the Authors' best knowledge, the research activity of all Greek university medical schools. Second, to compare the performance of the academics of the various ranks serving the medical schools in a nationwide basis and to discuss potential variations based on geographic, social or economic criteria. It must also be stressed that in the present study the evaluation of the research performance of all Greek medical schools is not limited to school level, calculating aggregate bibliometrics for the faculty, but it is extended to a more detailed comparison in an academic rank basis, calculating average bibliometrics for each academic rank separately as well. In this respect, bibliometric indices are also used to compare academics in the various ranks of each university separately. This detailed analysis shall shed light on the findings of the comparison of the medical schools in school level, while it will also reveal how research activity is distributed among the various academic ranks in each medical school.

Bibliometrics calculation and analysis

Bibliometric indices

The raw data, which composed the bibliometric profile of each researcher based on which the aggregate indices of each medical school and academic rank were calculated, consisted of the:

- number of published documents.
- number of citations with and without self-citations.
- h-index (Hirsch 2005) with and without self-citations, which takes into account both the number of publications and the number of citations. According to Hirsch (2005), a scientist has index h if h of his/her N_p papers have at least h citations each, and the other (N_p − h) papers have no more than h citations each.
- g-index (Egghe 2006) with and without self-citations, which gives more weight to the highly cited articles. According to Egghe (2006), a researcher has a g-index g if g is the highest rank such that the top g papers have, together, at least g^2 citations.

An accurate and complete study with bibliometrics cannot be based on isolated indices, but should be the result of the amalgamation of various scientometric indices, each one corresponding to different axis of research output, namely productivity, impact, efficiency and hybrid (i.e., productivity + impact) (Martin 1996; Vaxevanidis et al. 2011). In this respect, to compare the researchers in university and academic rank level, the following bibliometric indices were calculated for each medical school:

- total number of academics for each university (n) and for each academic rank separately: lecturers (n_l), assistant professors (n_{assi}), associate professors (n_{asso}) and professors (n_p) (obviously $n = n_l + n_{assi} + n_{asso} + n_p$).
- total number of published documents for each university faculty (P) and for each academic rank separately: lecturers (P_l), assistant professors (P_{assi}), associate professors (P_{asso}) and professors (P_p).
- average number of publications per academic in total (P_{ave}), given by the ratio of the total number of publications to the number of researchers of all ranks (P/n), and for each academic grade separately, given by the appropriate ratio (total number of publications of researchers of one academic rank divided by the number of researchers of the same rank), e.g. for lecturers ($P_{ave\text{-}l}$) it will be P_l/n_l.
- total number of citations with (C_s) and without (C) self-citations for each university faculty and for each academic rank separately.
- average number of citations per publication with (C_{aves}) and without self-citations (C_{ave}) for each university faculty, given by the ratio of the number of citations, with and without self-citations respectively, to the total number of documents (i.e., C_s/P and C/P respectively) and for each academic rank separately (in a similar way as previously described).
- average h-index with (h_{aves}) and without self-citations (h_{ave}) for each faculty and for each academic rank separately.
- median h-index with (h_{ms}) and without self-citations (h_m) for each faculty and for each academic rank separately, where median is the numerical value separating the higher half of a data sample from the lower half.
- average g-index with (g_{aves}) and without self-citations (g_{ave}) for each faculty and for each academic rank separately.
- median g-index with (g_{ms}) and without self-citations (g_m) for each faculty and for each academic rank separately.

As previously discussed, all bibliometric indices were also calculated for all academic ranks separately. At this point, to avoid any unnecessary repetitions, it should be pointed that for each rank the same symbol of the calculated index with the university faculty was used as stated above adding the appropriate index: "l" for lecturers, "assi" for assistant professors, "asso" for associate professors and "p" for professors. Few examples have already been given above.

In addition, all indices were calculated with and without self-citations in order to have a more complete study and to examine their significance on the bibliometrics calculation in the case of the faculty of medical schools.

Statistical analysis

The averaged bibliometrics were then statistically processed in order to determine whether statistically significant differences between the mean values of the calculated indices exist. For this purpose, one-way Analysis of Variance (ANOVA) was performed using suitable statistical software (STATISTICA 7, Statsoft, USA). ANOVA is a hypothesis-testing statistical method which tests the equality of two or more population means by examining the variances of the samples used determining whether the differences between the samples are due to random error or they can be attributed to systematic treatment effects, causing the mean value in one group to differ from the mean value in another (Scheffe 1959). After ANOVA, Tukey's HSD Post-hoc test was also performed, when the null hypothesis in ANOVA was rejected, to determine which of the studied groups (i.e., medical schools) differ significantly (Hsu 1996).

Methodology of data retrieval

Several studies have been conducted regarding which scientific database (Scopus, Web of Science, Google Scholar) is the most appropriate to retrieve the scientific data of a researcher necessary to calculate the bibliometric indices required for its performance evaluation (e.g. Bakkalbasi et al. 2006; Bar-Ilan 2008). Nevertheless, most of them seem to converge that, although Scopus and Web of Science remain very important resources and more accurate than Google Scholar, the final choice of the most accurate tool, in terms of providing the most complete set of citing literature, depends on the subject and publication date of a given article.

Based on the above, preliminary case studies were conducted for several researchers, selected in random, of all medical schools under consideration using both Scopus and Web of Science in order to locate their scientific record (i.e., number of published documents). Output results of both databases were then compared with data retrieved from their personal web pages or online curriculum vitae.

Since Scopus gave results closer to reality for the overwhelming majority (>90 %) of the cases studied, it was considered more appropriate scientific database for the present study (i.e., the discipline studied), while a more thorough comparison of these databases is beyond the scope of the present study.

As already discussed, in the present work the seven Greek medical schools were studied which host 1,803 academic staff members in total of all ranks, namely Lecturers, Assistant Professors, Associate Professors and Professors in ascending order of hierarchy. It should be noted that possession of a doctorate degree (Ph.D.) and an adequate number of publications is prerequisite for all four academic degrees.

The following list shows the schools studied, which are located in different geographic regions in Greece:

- Alexandroupolis Medical School, Democritus University of Thrace
- Athens Medical School, National and Kapodistrian University of Athens
- Heraklion Medical School, University of Crete
- Ioannina Medical School, University of Ioannina
- Larissa Medical School, University of Thessaly
- Patras Medical School, University of Patras
- Thessaloniki Medical School, Aristotle University of Thessaloniki

In the beginning of the study, the names, surnames, academic rank and expertise/specialty of all the academics were recorded in excel files separately for each medical school and they were categorized according to their academic degree. These data were retrieved from the departments' websites on December 18th 2012. Only tenured and at present active academic staff was included in the survey, while emeritus Professors were not taken into account.

As already mentioned, the Scopus database was used to locate an individual's publication record and more specifically the Author search form which is displayed clicking the Author Search tab. The same procedure was followed for all 1,803 academic staff members studied.

At first, only the surname of the under study researcher was entered in the field "*Last Name*" of the "*Author*", while the field "*Initials or First Name*" and "*Affiliation*" were left blank. This would ensure that all documents corresponding to the entered surname would be retrieved regardless the first name and the affiliation of the Author and that no documents would be excluded from the search. The resulting profile records would be selected or rejected accordingly manually, as described below.

For the sake of completeness and to be more correct, all subject areas were selected in order not to exclude documents from an author with multidisciplinary research work. Of course, this was not expected to be the case for the medical doctors composing the faculty of the medical schools. However, among the academic members hosted in the medical schools there were several researchers who were not medical doctors, but physicists, chemists or even computer scientists and their published documents would not be limited to the Health Sciences scientific area.

During the search of a researcher's record in Scopus several problems had to be tackled to assure the credibility of the results and the retrieval of the correct data. The most important difficulty confronted was the English transliteration of both Greek surnames and first names. Although most of the medical school web pages had the researchers' name in English, however the majority of them were not in the correct form the researcher used in their publications. Thus, the 'correct' spelling of their names was retrieved by their personal web pages, if they had one. In any case all possible spelling combinations were checked, as elucidated below.

Unfortunately, it was found that a considerable fraction of the faculty ($\sim$15–20 %) did not use the same spelling of their names in all of their publications or it had two surnames (concerning mainly female researchers). Consequently, they had more than one different records in Scopus corresponding to spelling variations of their surname or even of the first name, since there are several ways to spell Greek letter combinations in English due to pronunciation similarities; for example a name could contain "*b*" or "*mb*" or "*mp*", or double consonants (e.g. "*n*" or "*nn*") which when translated in Greek are pronounced the same (homophones). Moreover, spelling variations were not limited to the surnames but sometimes they were observed in the first or middle names as well (e.g. when the Greek first name was "*Ioannis*", records of the same person could be found with his first name as "*Ioannis*" but also as "*John*"). When that was the case, things were much easier since Scopus allows the user to merge different profile records (of the same surname) and view the citation overview as one when they are found in the same search. However, the above means that all records in each search were thoroughly checked to avoid neglecting data of the same person due to misspelling.

For this purpose, as already mentioned, all possible name spelling combinations (when translating from Greek to English) were considered for all researchers under study and multiple searches were accomplished for each one, thus demanding significant energy and time.

In all cases, in order to ensure that different variations in names correspond to the same person, several other parameters were also checked (especially when personal web pages or curriculum vitae were not available):

- The subject area of the published documents should be relevant to the under investigation researcher's discipline (e.g. for medical doctors it should be medicine, health sciences etc.).

- The affiliation was checked if it was the correct one.
- The discipline of the journals which the resulting documents were published in should be relevant to the researcher's expertise/specialty (e.g. for surgeons it should be related to surgery etc.).
- Affiliation and journal discipline were of great importance, since both contributed to avoid confusion between medical doctors with the same name (homonymy), but of different medical schools (different universities).
- If the affiliation was not the expected one, but the subject area and journal discipline matched, then it was also checked whether the co-authors of the resulting documents belong to the same faculty with the under study academic member, since a few researchers used in their publications past affiliations.
- In all cases, the year of the latest published documents was also checked. There were few cases of records of the same name and affiliation with the under study individual, but whose latest documents were published in the 70s or 80s and thus belonging to retired professors.

In each search, after selecting the desired profile (or profiles in case of merging different records of the same person as described above) the citation data were exported in a .csv file, which consisted of the documents, the citations and the *h*-index. For each researcher two different .csv files were exported; one with all citations considered and one excluding self-citations.

When multiple searches were needed to compose a researcher's record due to spelling variations, then the various proper .csv files (those including and those excluding self-citations, respectively) were subsequently merged in one single file separately, while the total number of documents, citations and *h*-index were calculated manually. For all researchers, the rest of the bibliometric indices were also calculated manually.

All academics' data were collected from 5th January 2013 to 25th February 2013 following the above described procedure. Although a change of the data is expected over time, i.e., number of publications and citations, it is regarded that it will only slightly affect the results, since data is used in the aggregate for each academic rank and medical school and for comparison reasons.

Finally, all data were tabulated for each medical school sorted by the academic ranks, in order to facilitate the calculation of all indices.

Results and discussion

Comparison of medical schools in school level

Table 1 gives the aggregate bibliometrics calculated in school level for all medical schools studied. It is obvious that there is a large variance between the faculty size of Athens and Thessaloniki medical schools and the rest of the medical universities with the two first having approximately 5 and 3 times more academics respectively than the rest and the latter having faculties of the same order of magnitude. This is not peculiar, since these are the first medical schools founded in Greece and also located on the two largest cities of the country.

Another observation from the absolute numbers of Table 1 is that Athens and Thessaloniki hold the two first positions as regards the total number of documents published, which was actually expected due to the much higher number of academics. However, it

Table 1 Aggregate bibliometrics calculated for all medical schools in school level

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
n	126	**685**	131	164	109	154	434
P	7,645	**49,292**	11,868	12,869	6,540	8,780	17,563
P_{ave}	60.67	71.96	**90.60**	78.47	60.00	57.01	40.47
C_s	78,729	**698,009**	200,423	202,699	74,508	98,583	181,761
C	73,009	**652,347**	185,870	187,395	68,090	91,306	170,834
C_{aves}	10.30	14.16	**16.89**	15.75	11.39	11.23	10.35
C_{ave}	9.55	13.23	**15.66**	14.56	10.41	10.40	9.73
h_{aves}	10.57 (7.68)	12.76 (8.55)	**17.53** (8.60)	14.08 (10.18)	11.68 (6.24)	11.62 (5.19)	7.94 (6.29)
h_{ave}	10.15 (7.26)	12.26 (8.11)	**16.60** (8.17)	13.40 (9.53)	11.16 (5.76)	11.03 (4.89)	7.66 (6.00)
h_{ms}	9.00	11.00	**17.00**	12.00	11.00	11.00	7.00
h_m	8.00	11.00	**16.00**	11.00	11.00	10.00	7.00
g_{aves}	17.13 (12.86)	21.72 (15.42)	**29.11** (15.08)	23.92 (16.71)	19.49 (9.98)	19.19 (9.21)	13.38 (11.36)
g_{ave}	16.56 (12.32)	21.04 (14.84)	**27.95** (14.77)	23.01 (15.92)	18.69 (9.37)	18.44 (8.91)	13.02 (10.96)
g_{ms}	13.00	19.00	**27.00**	20.00	19.00	18.00	11.00
g_m	13.00	18.00	**26.00**	18.50	18.00	17.00	11.00

Numbers in bold font indicate the highest value in each row; Numbers in brackets denote the standard deviation

seems that this is not the case when values are averaged, since the rest of the bibliometric indices depict a different trend.

More specifically, the Heraklion medical school exhibits the highest values in all bibliometric indices in all four axes of research output, as previously discussed, with the Ioannina medical school following. The above excellence of Heraklion medical school is remarkable, with its bibliometrics being significantly higher than the corresponding ones of all other schools. Its distinction could be attributed to the incessant research being conducted especially in the fields of drug development and cancer therapy.

On the other hand, Athens drops to the third place of the school quality list, although the median h- and g-indices are the same with those of Larissa and Patras, while Thessaloniki appears to be in the last place and to lag far behind the other universities. Finally, Larissa, Patras and Alexandroupolis display comparable bibliometrics, with the latter exhibiting slightly lower median and average h- and g-indices per academic than the former two.

The above finding is very interesting and it seems that academics in the more recently founded medical universities can more easily manage their time and balance their duties, achieving better quality in their research.

In order to further assess the above results, statistical analysis of the data was also performed. More specifically, Fig. 1 illustrates the one way ANOVA of the average h-index (calculated without self-citations) for all medical schools, performed with confidence interval 95 %, while results of ANOVA are presented in Table 2.

Since F (6, 1796) = 33.48 > 2.10, the analysis is significant, meaning that at least one of the mean values of the h-index of the medical schools differs significantly from the others. In order to further examine the relationship of h_{ave} among all groups, the Tukey's HSD Post-hoc test is performed and the results in the form of p values (significance levels) for the respective pairs of weighted marginal means are given in Table 3.

From Fig. 1 and Table 3, it is obvious that results of ANOVA and Tukey's HSD Post-hoc test lead to the same conclusions as previously discussed. More specifically, the h_{ave} of Heraklion medical school is the highest one and significantly different from the h_{ave} of all

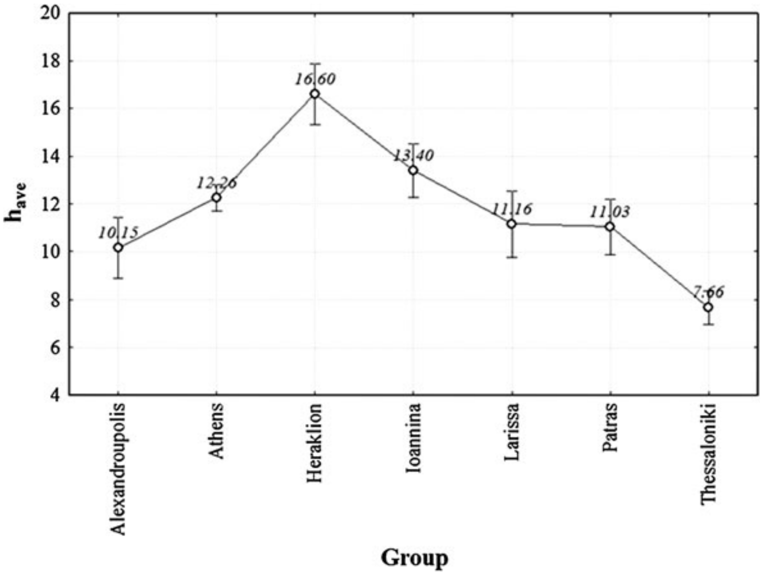

Fig. 1 One way ANOVA of the h_{ave} for all medical schools; *Vertical bars* denote 0.95 confidence intervals

Table 2 Results of one way ANOVA applied on h_{ave} for all medical schools in school level

Source of variation	Sum of Squares (SS)	Degrees of freedom (*df*)	Mean square (MS)	*F*	*p* value	*F* critical
Between groups	10,946.23	6	1,824.37	33.48	0.000	2.10
Within groups	97,861.43	1,796	54.49			
Total	108,807.66	1,802				

Table 3 Results of Tukey's HSD Post-hoc test after ANOVA of h_{ave} in school level

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
Alexandroupolis		**0.0498**	**0.0000**	**0.0038**	0.9445	0.9554	**0.0152**
Athens	**0.0498**		**0.0000**	0.5629	0.7732	0.5027	**0.0000**
Heraklion	**0.0000**	**0.0000**		**0.0042**	**0.0000**	**0.0000**	**0.0000**
Ioannina	**0.0038**	0.5629	**0.0042**		0.1731	0.0639	**0.0000**
Larissa	0.9445	0.7732	**0.0000**	0.1731		1.0000	**0.0002**
Patras	0.9554	0.5027	**0.0000**	0.0639	1.0000		**0.0000**
Thessaloniki	**0.0152**	**0.0000**	**0.0000**	**0.0000**	**0.0002**	**0.0000**	

Numbers in bold font indicate $p < 0.05$

other schools. In the same respect, Thessaloniki has the lowest h_{ave} which significantly differs from the h_{ave} of all other schools. In addition, it seems that Athens, Ioannina, Larissa and Patras do not have significantly different h_{ave}, while the same seems to be valid for the h_{ave} of Alexandroupolis, Larissa and Patras.

Comparison of medical schools in academic rank level

Cumulative bibliometrics of all researchers of the seven (7) medical schools studied calculated for each academic rank are presented in Table 4. As already discussed, it is obvious that Athens and Thessaloniki hold the first two positions when values are not averaged, since they host the most numerous academics not only in total, but in each rank as well.

In other respects, the ranking seems to be similar as presented in the comparison of the schools in school level. This means that, according to the bibliometric indices (averaged and median) Heraklion is again at the helm of the research activity even in academic rank level. All ranks separately exhibit much higher bibliometrics than the relative ones of the other medical schools, although small variations are observed in few indices as regards academics of 1st rank, namely professors. In detail, Athens and Ioannina display slightly higher average publications per professor ($P_{\text{ave-p}}$) than Heraklion, while professors in Ioannina alone demonstrate marginally higher values of average citations with and without self-citations per publication ($C_{\text{aves-p}}$ and $C_{\text{ave-p}}$ respectively) compared to Heraklion. However, these variances can be considered negligible and cannot distort the overall image for the research performance quality of Heraklion medical school, as depicted by all bibliometric indices.

In a similar way, Ioannina seems to be in second place, since the majority of the bibliometric indices are considerably higher than those of the other six universities, while Thessaloniki scores last in indices for all academic ranks separately, although some of them are comparable to those of the other three universities (i.e., Alexandroupolis, Larissa and Patras), which further justifies and its last position in the overall ranking as discussed earlier.

Alexandroupolis, Larissa and Patras appear to have comparable indices in most cases, although few variations for the various ranks among the three aforementioned schools are observed which are worth mentioning. Alexandroupolis exhibits higher average values in calculated bibliometrics for professors, while the same seems to be valid for Larissa for all indices in the case of associate professors. In addition, assistant professors of Patras appear superior to researchers of the same rank hosted in the other two universities, while solid conclusions cannot be extracted for lecturers, since their bibliometrics are similar for the three schools.

Comparing the bibliometrics (especially the averaged ones) for the various academic ranks in each university separately, interesting conclusions can also be extracted about the research performance in rank level for each school. Figure 2 illustrates the average h-index (calculated without self-citations) (Table 4) of each academic rank for all Greek medical schools. It must be noted that the observed trend is typical, since it is similar for all hybrid axis bibliometric indices of Table 4 in all universities.

From Fig. 2, one can readily observe that in six of the seven medical universities the average h-index increases moving to higher academic ranks. The above means that, as expected, there is a consistency regarding the progress in the research performance and impact of academics of different ranks, with those of higher rank exhibiting more improved and acknowledged scientific profile. New researchers and, thus of lower academic grade, have less recognizable scientific work leading to lower bibliometrics (although several exceptions do exist in individual scale).

However, this is not the case for the medical school of Thessaloniki (Table 4; Fig. 2), where a peculiar behavior is observed. In all bibliometric indices, associate professors exhibit very low values, lower even than those of the lecturers. Nevertheless, the order in the research performance for the other three ranks complies with the previous trend.

Table 4 Aggregate bibliometrics calculated for all medical schools in academic rank level

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
n_{l}	22	**119**	17	26	23	14	80
n_{assi}	43	**247**	52	57	37	50	134
n_{asso}	27	**209**	24	40	21	38	82
n_{p}	34	110	38	41	28	52	**138**
P_{l}	635	**4,433**	773	1,182	643	306	2,584
P_{assi}	1,957	**13,156**	2,963	2,775	1,680	2,344	4,979
P_{asso}	1,298	**14,131**	2,264	2,546	1,368	1,884	2,476
P_{p}	3,755	**17,572**	5,868	6,366	2,849	4,246	7,524
$P_{ave\text{-}l}$	28.86	37.25	**45.47**	45.46	27.96	21.86	32.30
$P_{ave\text{-}assi}$	45.51	53.26	**56.98**	48.68	45.41	46.88	37.16
$P_{ave\text{-}asso}$	48.07	67.61	**94.33**	63.65	65.14	49.58	30.20
$P_{ave\text{-}p}$	110.44	**159.75**	154.42	155.27	101.75	81.65	54.52
$C_{s\text{-}l}$	5,353	**51,896**	10,645	14,802	5,084	2,821	23,463
$C_{s\text{-}assi}$	12,211	**180,418**	47,011	37,629	16,905	27,241	54,809
$C_{s\text{-}asso}$	11,048	**190,123**	38,019	33,910	17,485	22,512	21,815
$C_{s\text{-}p}$	50,117	**275,572**	104,748	116,358	35,034	46,009	81,674
C_{l}	4,985	**48,509**	9,839	13,638	4,663	2,723	22,339
C_{assi}	11,395	**170,091**	44,199	35,506	14,868	25,529	51,656
C_{asso}	10,368	**178,332**	35,909	31,296	16,285	20,420	20,558
C_{p}	46,261	**255,415**	95,923	106,955	32,274	42,634	76,281
$C_{aves\text{-}l}$	8.43	11.71	**13.77**	12.52	7.91	9.22	9.08
$C_{aves\text{-}assi}$	6.24	13.71	**15.87**	13.56	10.06	11.62	11.01
$C_{aves\text{-}asso}$	8.51	13.45	**16.79**	13.32	12.78	11.95	8.81
$C_{aves\text{-}p}$	13.35	15.68	17.85	**18.28**	12.30	10.84	10.86
$C_{ave\text{-}l}$	7.85	10.94	**12.73**	11.54	7.25	8.90	8.65

Table 4 continued

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
$C_{\text{ave-assi}}$	5.82	12.93	**14.92**	12.79	8.85	10.89	10.37
$C_{\text{ave-asso}}$	7.99	12.62	**15.86**	12.29	11.90	10.84	8.30
$C_{\text{ave-p}}$	12.32	14.54	16.35	**16.80**	11.33	10.04	10.14
$h_{\text{aves-l}}$	6.64 (4.79)	9.77 (5.61)	**13.06** (6.13)	11.15 (6.20)	7.00 (4.11)	6.50 (4.05)	6.84 (5.14)
$h_{\text{aves-assi}}$	8.02 (3.50)	11.46 (7.07)	**14.81** (6.00)	11.00 (5.64)	10.62 (5.60)	11.30 (5.27)	8.10 (6.58)
$h_{\text{aves-asso}}$	10.07 (4.65)	12.39 (7.93)	**19.04** (9.42)	12.93 (10.38)	13.14 (5.87)	12.03 (5.16)	6.32 (4.95)
$h_{\text{aves-p}}$	16.74 (10.87)	19.65 (11.41)	**22.32** (9.72)	21.34 (13.20)	15.82 (5.89)	13.02 (4.60)	9.38 (7.00)
$h_{\text{ave-l}}$	6.32 (4.31)	9.42 (5.41)	**12.41** (6.03)	10.65 (5.91)	6.61 (3.69)	6.21 (3.81)	6.60 (4.86)
$h_{\text{ave-assi}}$	7.74 (3.29)	11.05 (6.72)	**14.19** (5.64)	10.53 (5.41)	9.92 (4.77)	10.90 (4.95)	7.91 (6.39)
$h_{\text{ave-asso}}$	9.63 (4.39)	11.88 (7.53)	**18.25** (9.00)	12.23 (9.53)	12.71 (5.24)	11.29 (4.84)	6.12 (4.73)
$h_{\text{ave-p}}$	16.09 (10.24)	18.78 (10.75)	**20.71** (9.46)	20.29 (12.33)	15.36 (5.56)	12.27 (4.41)	8.96 (6.58)
$h_{\text{ms-l}}$	6.00	9.00	**11.00**	9.00	6.00	7.00	6.00
$h_{\text{ms-assi}}$	8.00	10.00	**14.50**	11.00	10.00	10.00	6.00
$h_{\text{ms-asso}}$	9.00	11.00	**19.00**	10.00	13.00	11.00	6.00
$h_{\text{ms-p}}$	13.00	16.50	**20.00**	19.00	16.00	12.50	8.00
$h_{\text{m-l}}$	5.00	9.00	**11.00**	9.00	5.00	6.50	6.00
$h_{\text{m-assi}}$	8.00	10.00	**13.50**	10.00	10.00	10.00	6.00
$h_{\text{m-asso}}$	9.00	10.00	**18.50**	9.50	12.00	10.00	5.50
$h_{\text{m-p}}$	13.00	16.00	**18.00**	**18.00**	16.00	12.00	8.00
$g_{\text{aves-l}}$	11.41 (7.96)	16.46 (9.99)	**21.35** (9.10)	19.12 (11.19)	12.17 (6.29)	11.07 (7.17)	12.10 (9.92)
$g_{\text{aves-assi}}$	12.98 (5.73)	20.13 (13.08)	**24.90** (10.93)	20.26 (11.65)	17.32 (8.47)	19.02 (9.30)	13.69 (11.60)
$g_{\text{aves-asso}}$	15.78 (7.82)	20.92 (14.78)	**30.67** (14.77)	20.78 (12.78)	21.76 (9.30)	19.16 (8.82)	10.56 (8.64)
$g_{\text{aves-p}}$	27.18 (18.62)	32.50 (20.66)	**37.34** (18.42)	35.12 (23.18)	26.64 (9.86)	21.56 (8.85)	15.49 (12.88)
$g_{\text{ave-l}}$	10.95 (7.48)	15.90 (9.66)	**20.29** (9.14)	18.31 (10.54)	11.78 (5.96)	10.93 (7.19)	11.86 (9.74)
$g_{\text{ave-assi}}$	12.58 (5.64)	19.57 (12.61)	**24.06** (10.58)	19.67 (11.41)	16.32 (7.62)	18.40 (9.01)	13.41 (11.21)

Table 4 continued

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
$g_{\text{ave-asso}}$	15.33 (7.55)	20.26 (14.29)	**29.88** (14.59)	19.95 (11.82)	21.14 (8.48)	18.21 (8.27)	10.26 (8.28)
$g_{\text{ave-p}}$	26.21 (17.75)	31.38 (19.76)	**35.47** (18.30)	33.63 (22.12)	25.64 (9.42)	20.65 (8.76)	14.94 (12.38)
$g_{\text{ms-l}}$	9.50	14.00	**19.00**	15.50	12.00	11.50	10.00
$g_{\text{ms-assi}}$	12.00	17.00	**23.00**	17.00	16.00	19.00	11.50
$g_{\text{ms-asso}}$	14.00	19.00	**28.00**	17.00	20.00	17.00	9.00
$g_{\text{ms-p}}$	20.00	26.00	**31.50**	29.00	27.00	21.00	13.00
$g_{\text{m-l}}$	9.50	13.00	**18.00**	15.00	12.00	11.50	9.00
$g_{\text{m-assi}}$	12.00	17.00	**22.50**	17.00	15.00	18.00	11.50
$g_{\text{m-asso}}$	14.00	18.00	**27.00**	17.00	19.00	16.50	9.00
$g_{\text{m-p}}$	19.00	25.00	**29.50**	28.00	26.00	20.00	12.50

Numbers in bold font indicate the highest value in each row; Indices at symbols of bibliometrics denote: "l" lecturers, "assi" assistant professors, "asso" associate professors and "p" professors; Numbers in brackets denote the standard deviation

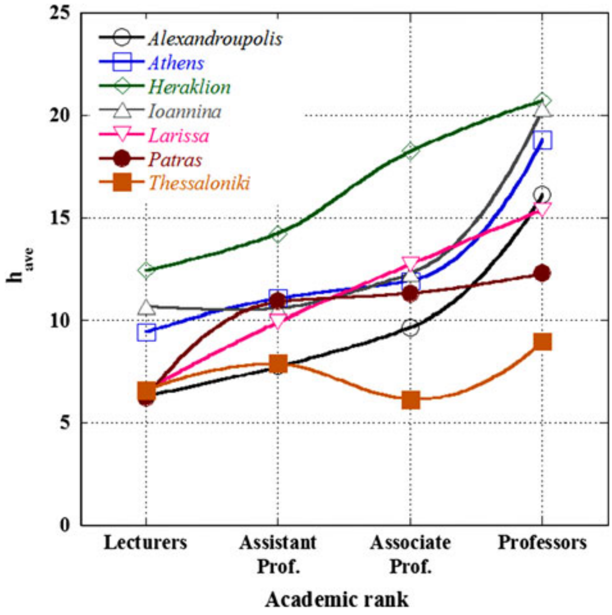

Fig. 2 Average *h*-index (calculated without self-citations) of the various academic ranks for all universities studied

In parallel, it is also worth noticing that standard deviations for the average *h*- and *g*-indices of all the seven medical schools calculated for each academic rank are also presented in Table 4. Standard deviations of these bibliometric indices, in conjunction with a comparison between the average and median values, can give valuable information about the heterogeneity in each rank of the schools studied, regarding the research profile of academics of the same rank. In the case of Heraklion, the standard deviations of the average *h*- and *g*-indices are relatively low when compared to the corresponding average values in all academic ranks, indicating that dispersion and heterogeneity among the indices of academics of the same rank is low.

In the same respect, the above seems also to be valid for the heterogeneity in all academic ranks of Ioannina, Patras and Larissa, while for the rest of the schools heterogeneity varies with the academic rank. In Alexandroupolis, average indices in lecturers and professors exhibit relatively high standard deviations, while in Athens, despite the relatively high standard deviations in the average indices of all ranks, concrete conclusions regarding their heterogeneity cannot be extracted. Finally, in Thessaloniki, it seems that dispersion in all academic ranks is high, since standard deviations and average values are of the same order of magnitude.

Effect of self-citations on bibliometrics of medical schools

Calculation of bibliometric indices with and without researchers' self-citations in the present study allows extracting some conclusions about whether self-citations influence the assessment of academics' or school's research performance. As regards the total number of citations, Table 5 presents its percentage increase when self-citations are taken into account, for all academic ranks separately and for each school in total.

Table 5 Percentage (%) increase in number of citations when self-citations are considered

	Alexandroupolis	Athens	Heraklion	Ioannina	Larissa	Patras	Thessaloniki
Lecturers	7.38	6.98	8.19	8.53	9.03	3.60	5.03
Assistant Prof.	7.16	6.07	6.36	5.98	13.70	6.71	6.10
Associate Prof.	6.56	6.61	5.88	8.35	7.37	10.24	6.11
Professors	8.34	7.89	9.20	8.79	8.55	7.92	7.07
School	7.83	7.00	7.83	8.17	9.43	7.97	6.40

Percentage is calculated by $(C_s - C) \times 100/C$

Table 6 Number and percentage (%) of researchers whose h-index either remained constant or increased when self-citations are considered

h-index increment	Number of academics	Percentage of academics (%)
0	1,180	65.45
1	456	25.29
2	107	5.93
3	33	1.83
≥4	27	1.50
Total	1,803	100.00

From Table 5, it is apparent that the effect of self-citations varies with both the academic rank and the school. The average increase in the number of citations considering the bibliometric profile of all academics studied (1,803) when self-citations are taken into account is ~7.4 %.

The effect of self-citations on the research performance evaluation is further investigated comparing the h-index values with and without self-citations in researcher level. For this purpose Table 6 is constructed which presents the number and the percentage of all 1,803 academics studied, whose h-index either remained unaffected or increased (along with the relevant increment) when self-citations are considered in its calculation.

From Table 6, it is evident that the impact of self-citations on the h-index is practically negligible in the case of the academic medical doctors, since h-index did not change at all (60.45 %) or increased only by one (25.29 %) in 90.74 % of all academics studied.

In this respect, the effect of self-citations is also studied on the average h-index of each academic rank and university. For this purpose Fig. 3 is drawn which depicts the average h-index with and without self-citations for each academic rank of all medical schools along with the total ones of each medical school. The solid and dashed lines correspond to the lines $h_{\text{aves}} = h_{\text{ave}}$ and $h_{\text{aves}} = h_{\text{ave}} + 1$, i.e., when h-index remains unchanged or increases by one if self-citations are also considered in its calculation, respectively.

From Fig. 3 it is apparent that in 33 out of the 35 average h-indices, in rank and school level, self-citations have negligible effect on h-index calculation, while in 2 out of 35, h-index increases just by one. Consequently, it seems that assessment of the research activity of medical doctors is not influenced by self-citations.

Discussion and conclusions

The use of bibliometrics for individual and university evaluation is highly recommended by several investigators. Abramo and D'Angelo (2011) view bibliometrics as by far

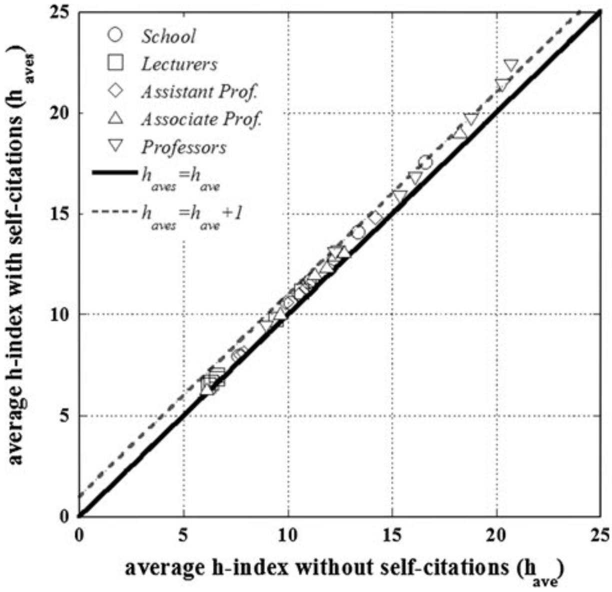

Fig. 3 Comparison between average h-index with and without self-citations in academic rank and school level

preferable evaluation method in terms of robustness, validity, functionality, costs and time of execution. In this respect, in the present work, the 1,803 academics that compose the seven Greek medical schools are bibliometrically studied calculating various advanced and widely accepted indices, in order to evaluate their research activity in academic rank and school level. The methodology adopted for the creation of each researcher's bibliometric profile assures the quality of the present work, since it minimizes the potential errors involved mainly due to spelling variations of the Greek names in English.

Bibliometrics indicate that the medical school of Heraklion exhibits significant performance in all academic ranks considerably superior to that of the other six medical schools, which seems to reflect the continuous research conducted in this school in several fields of medicine. On the contrary, medical school of Thessaloniki presents in general the lowest values in almost all bibliometric indices, in spite of its large faculty size. Schools of Alexandroupolis, Larissa and Patras have comparable bibliometric indices, although few variations do exist when comparing them in academic rank level. One way analysis of variance of all schools' h_{ave} in conjunction with Tukey's HSD Post-hoc test was also performed which supported the above findings.

In addition, a consistency between academic ranks and research performance is evident, with average bibliometric indices being higher for academics of higher rank. This trend is expected and it is consistent with the findings of Vaxevanidis et al. (2011) who argue that younger researchers have lower bibliometric indices, since they are not involved many years in the research process and their levels of publications are relatively low. In addition, Costas and Bordons (2011) underline that individual's academic rank is strongly connected to its role and contribution in the published research. As researchers go up in the hierarchy, they have a role of supervision and leadership of the research (Beveridge and Morris 2007; Shapiro et al. 1994), a 'privilege' those of lower academic rank do not have to the same extent. Consequently, as the number of research projects an academic has under their supervision augments so do the published documents with their name, regardless the significance of their contribution in research, which actually occurs as the researcher is gradually promoted to higher academic ranks. Nevertheless, a peculiar pattern is observed in Thessaloniki, where the above trend is not observed but associate professors display the lowest bibliometrics of all academic ranks.

Furthermore, results show that different conclusions can be extracted about the heterogeneity in each academic rank for the seven schools studied. In any case, this is an implicit indicator of the fact that no standards regarding the research profile of an individual (minimum publications and/or citations for each academic rank) are established in the university hiring and/or promoting policies.

Finally, according to the results of the present study, the impact of self-citations on bibliometrics is negligible and cannot influence the evaluation of the research performance of academics in medical schools. According to the literature it seems that a controversy exists about the impact of self-citations on the bibliometric profile of researchers. May (1997) states that self-citations may bias some of the bibliometric indices. In the same respect, Vinkler (2007) argue that self-citations should be excluded when calculating scientometric indices for individuals, while Bartneck and Kokkelmans (2011) found that authors can considerably inflate their *h*-index through self-citations. On the other hand, Huang and Lin (2011) who investigated 583 researchers in the field of environmental engineering found that self-citations have little impact on the values of *h*-index and the *h*-index rankings. Similarly, Rad et al. (2012) who evaluated the role of self-citations on the *h*-index in a medical field, namely academic radiology, found that self-citations increase cumulative citations by only 2 %, while the large majority of *h*-index values do not change by even a single integer after inclusion of self-citation, akin to the findings of the present study. According to the above, it seems that the effect of the self-citations on bibliometrics is ambiguous and strongly depends on the scientific discipline of the researchers studied, a statement also supported by Aksnes (2003).

Since rankings provide recognition to those who do well and at the same time they spur competition between universities (Lazaridis 2010), the findings of the present study can and should serve as the starting point for deep consideration and as the driving force for improvement in the research field of medicine in Greek medical schools.

Additionally, the resulted knowledge could help young researchers choose the school in which to conduct research. Nevertheless, it should be pointed that results of the present study stem from indices based only on published material of the faculty and represent just a fraction of the total quality of each medical school, the definition of which demands several other factors to also be taken into account.

The aforementioned methodology could also be applied to an European and/or international scale to achieve a comparison across the medical schools of Europe and/or United States and investigate the ranking of Greek medical school research performance in an international level. In parallel, future study should investigate whether bibliometrics of the research output can also be regarded as implicit indicators of other quality parameters such as funding, laboratory equipment, infrastructures etc.

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