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The research activity of the current faculty of the Greek chemical engineering departments: a bibliometric study in national and international context

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Abstract The object of the present study is the evaluation of the research quality of the three Greek chemical engineering departments (Athens, Thessaloniki, Patras) by means of several advanced bibliometric indices calculated separately for each academic using a twofold approach, namely in department and academic rank level. This allows the ranking of the studied departments, but also sheds light on the distribution of the research activity among the various ranks. In addition, to assess the research profile and background of the current faculty of the Greek chemical engineering departments in International context their research output is compared with that of Massachusetts chemical engineering department, Massachusetts Institute of Technology (MIT). Dependency of the bibliometric indices on seniority is also investigated, conducting the bibliometric analysis using a common time basis for all academics, i.e., research performance during the last decade. Available data are also used to investigate the temporal progress of the research productivity. Finally, gender distribution among the academics of the various ranks is also studied to explore the gender balance in research. In general, bibliometrics demonstrate that Patras department host academics of better quality, with higher scientific activity over the last decade, but superiority of MIT department against the Greek departments is also evident. Results also indicate that no common standards in hiring/promotion of academics are established between the departments. The negative impact of the European socio-economic crisis on the research productivity is also highlighted, while the university system suffers from unequal gender distribution with pronounced male dominance.

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Introduction—research aims

Quality evaluation and its assurance in higher education institutions constitute a core component of most countries in a global scale. However, quality is hard to define when it refers to higher education, and thus there is a need to agree internationally on terms such as levels, standards, effectiveness and efficiency (Frazer 1994). For this purpose, the European Association for Quality Assurance in Higher Education (ENQA) has developed agreed set of standards, procedures and guidelines (ENQA 2009) to be implemented in the most important axes on quality assurance that constitute the cornerstone of the university purpose, namely:

- tuition
- research
- curriculum
- other services-features (e.g. facilities, employability, internationalization)

Towards this direction, a new legislation (Legislation 3374/2005) was enacted in Greece, which as a member of the European Union should also set the standards and procedures of quality assessment of Greek higher education institutions and define all structural and institutional reforms that should be implemented to achieve the above. According to the above law, widely accepted qualitative and quantitative indices must be used in order to evaluate the quality of the above axes and to conform to the Bologna Process.

Evaluation of the above axes demands their quantification by means of appropriate indices, which would also facilitate the comparison of departments of the same discipline in a European or even global scale. However, to accomplish the above, access to specific data is compulsory, which in most cases, without being confidential, can only be retrieved in collaboration with each institution administration.

Nevertheless, internet proliferation has enabled access to personal records of academics regarding their research activity, thus, allowing the quantification and assessment of one of the above axes, namely the research performance of university faculty, by means of bibliometrics. Bibliometrics is a useful tool for quantification of the research performance and it offers a relatively impartial way to compare the research activity (productivity and impact) between researchers and universities of the same discipline (e.g. Lazaridis 2010; Zachos 1991). In addition, such bibliometric studies of the research performance of universities inadvertently lead to the ranking of universities which is valuable from many points of view. Such rankings provide recognition to those who do well and at the same time they could spur healthy competition between universities (Lazaridis 2010), while they can also serve as the starting point for deep consideration and as the driving force for improvement.

In this respect, only few are the published studies regarding the evaluation of Greek university departments using bibliometrics (e.g. Altanopoulou et al. 2012; Katsaros et al. 2008; Kazakis 2014; Kazakis et al. 2014; Lazaridis 2010; Vaxevanidis et al. 2011, 2013; Zachos 1991). In the present work the research activity of the three Greek chemical

engineering departments hosting a total of 136 academics is studied in detail by means of several indices, while their research performance is also compared with one of the most reputable departments in the world to determine its current status globally.

Such a study is of great interest since chemical engineering is a multi-disciplinary branch of engineering and indeed a fascinating scientific field, which combines natural and experimental sciences, along with life sciences. Its applications are not limited to the design, development and operation of industrial processes, but they also involve many biomedical advancements regarding faster disease diagnosis, more efficient drug-delivery mechanisms and improved biomaterials. In addition, Grant et al. (2011), in a recent review about research in Greece found that the research output from the chemical engineering field is in the first position regarding its scientific impact, since it displays the highest number of papers that are in the top 20 % of citations for this field worldwide.

The scope of the present paper is manifold. First, to investigate the research profile of researchers of the chemical engineering discipline and record with detailed bibliometric indices for the first time, to the Author's best knowledge, the research activity of all Greek chemical engineering departments. Second, to compare the performance of the academics of the various ranks serving these departments in a nationwide basis revealing how research activity is distributed among the various academic ranks and to discuss potential variations. Third, to investigate the research age and the actual productive period and annual rate of the academics of the various ranks, using time-averaged and time-related bibliometrics, shedding light on their maturity and experience in temporal basis. Fourth, to evaluate the research status of the current faculty of the Greek chemical engineering departments in International context, comparing it with the research output of one of the most recognizable chemical engineering departments in the world. Fifth, to explore the dependence of all bibliometrics on academic seniority making an additional bibliometric analysis considering the research profiles of all academics only for the last decade. Sixth, to examine the temporal evolution of the research productivity and seventh, to study if and how gender differences affect the opportunity to achieve professorship in the chemical engineering departments.

Methods

Data retrieval methodology

All raw data of each researcher required for the calculation of the bibliometric indices were retrieved using the Scopus scientific database (see also Kazakis et al. 2014).

In the present work the three Greek chemical engineering departments were studied which host 136 academic staff members in total of all ranks (Lecturers, Assistant Professors, Associate Professors and Professors). The following list shows the departments studied:

- Athens chemical engineering department, National Technical University of Athens
- Patras chemical engineering department, University of Patras
- Thessaloniki chemical engineering department, Aristotle University of Thessaloniki

For comparison purposes, the research performance of one of the world's most acknowledged and reputable chemical engineering departments was also studied:

- Massachusetts chemical engineering department, Massachusetts Institute of Technology (called MIT hereafter)

Besides its reputation, MIT was also considered an excellent choice for comparison purposes, since academic ranks in US are similar to those used in the Greek academic system. The only difference concerns the lecturers, who in US are defined differently. In US a lecturer is a person who teaches at a university but is not eligible for tenure and has no research obligations, while possession of a doctorate degree may not be a prerequisite. Other than that, the other three academic ranks are common both in Greece and MIT. Consequently, in the case of MIT, lecturers were excluded and only academics of the three common ranks were taken into consideration in the present study, namely 38 academics.

The methodology followed was similar to the one of Kazakis et al. (2014) and Kazakis (2014), where it is described in detail along with all actions performed to assure the credibility of the results and the retrieval of the correct data. All personal details of the faculties (e.g. name, surname, academic rank etc.) were retrieved from the departments' websites on June 15th 2014, while all academics' data were collected from 25th June 2014 to 30th June 2014.

Bibliometrics calculation

The raw data composing the bibliometric profile of each academic comprise the:

- number of published documents for each year.
- number of citations (including self-citations) that corresponds to each document.
- research age, which is actually given by the total research years of each individual, namely the difference between the year of the first publication and today (2014).
- productive years, which represent the actual research years, and they are given by the number of years during which at least one document was published.
- average number of publications per year, given by the ratio of the total number of publications to the research age of each academic.
- *h*-index (Hirsch 2005).
- *g*-index (Egghe 2006).

The bibliometric indices calculated in both department and academic rank level are the same with those in the civil engineering departments bibliometric study (see Kazakis 2014). In addition, several other *time-related* and *time-averaged* indices were also calculated in order to extract concrete conclusions about the research performance of all academics studied, namely:

- average research age (ra_{ave}) for each faculty (given by the sum of the research ages of all researchers divided by the number of researchers of all ranks) and for each academic rank separately.
- median research age (ra_{m}) for each faculty and for each academic rank separately.
- average productive years (pry_{ave}) for each faculty (given by the sum of the productive years of all researchers divided by the number of researchers of all ranks) and for each academic rank separately.
- median productive years (pry_{m}) for each faculty and for each academic rank separately.

- average number of publications per year per academic (Py_{ave}) for each faculty (given by the sum of the publications per year of all researchers divided by the number of researchers of all ranks) and for each academic rank separately.
- median publications per year per academic (Py_m) for each faculty and for each academic rank separately.

All bibliometrics were calculated twice, namely considering the complete research profile of each academic with no time limit and taking into account the documents and corresponding citations only for the last decade (period 2004–2014) (see Kazakis 2014).

In the first case, in the calculation of the *time-related* and *time-averaged* indices the research age of each academic was considered, while in the latter, since publications till the end of June 2014 were taken into account for all researchers, the actual "decade" period employed in all required calculations was 10.5 years and not 10 years. Of course, it should be noted that in this case the research age for all researchers is the same (i.e., 10.5 years) and thus the average and median research ages are not applicable. On the contrary the productive years for each academic have a meaning and refer to the actual research years (as previously defined) during the last decade. According to the above, a value of "11" for the productive years index during the period 2004–2014 is acceptable.

Statistical analysis

The statistical difference between the mean values of the calculated indices was investigated employing one-way Analysis of Variance (ANOVA). For further details see also Kazakis et al. (2014).

Table 1 Aggregate bibliometrics calculated for all chemical engineering departments in department level

Index	Athens	Thessaloniki	Patras	MIT
n	**72**	34	30	38
P	**4,463**	2,253	2,573	7,862
P_{10}	**2,289**	1,365	1,280	4,366
P_{ave}	62.0	66.3	**85.8**	206.9
P_{ave10}	31.8	40.1	**42.7**	114.9
C_s	**74,368**	39,695	63,718	325,842
C_{s10}	**26,092**	18,589	23,875	147,212
C_{aves}	16.7	17.6	**24.8**	41.4
C_{aves10}	11.4	13.6	**18.7**	33.7
h_{aves}	16.3 (8.0)	16.8 (8.5)	**21.3** (13.5)	38.2 (27.5)
h_{aves10}	9.4 (4.8)	11.6 (6.5)	**13.1** (9.0)	25.7 (19.0)
h_{ms}	15.5	17.0	**18.0**	35.5
h_{ms10}	9.5	**12.0**	11.0	22.0
g_{aves}	26.8 (12.6)	28.3 (13.9)	**35.5** (23.0)	69.4 (47.6)
g_{aves10}	16.3 (7.6)	19.5 (10.6)	**21.8** (15.8)	48.2 (33.5)
g_{ms}	26.5	27.0	**30.5**	63.0
g_{ms10}	17.0	**20.5**	16.5	42.0

Numbers in bold font indicate the highest value among the Greek departments in each row; Index "10" at the symbols indicate that the bibliometric index was calculated considering the scientific output of only the last 10 years (2004–2014); Numbers in brackets denote the standard deviation

Results and interpretation

Comparison of the Greek chemical engineering departments in department level

Table 1 gives the aggregate bibliometrics calculated in department level for all departments studied (Greek and MIT).

From Table 1, it is obvious that the Athens department hosts more than double academics than the other two departments, probably due to its age and location (capital of Greece). On the other hand, Thessaloniki and Patras, which have been founded almost at the same time have faculty of comparable size at present. Looking at the absolute numbers of the bibliometrics, one can readily observe the superiority of Athens department in the total number of publications and citations, with the former being almost double than the ones of Thessaloniki and Patras. The above is actually expected due to the significantly larger faculty size of Athens, which results in a stronger accumulation of published documents.

However, a completely different pattern is depicted when the average values are considered. Results indicate that the Patras chemical engineering department displays the highest values in all bibliometric indices indicating that academics hosting it have been more scientifically dynamic through their career. On the other hand, departments of Athens and Thessaloniki exhibit much lower values than the ones of Patras. It is worth mentioning that the average number of publications per academic in total (P_{ave}) and the average number of citations per publication (C_{aves}) are almost 30 and 40 % respectively lower than the corresponding ones of Patras. In the same respect, the department of Patras demonstrates a h_{aves} value of more than 25 % higher than that of Athens and Thessaloniki. However, since Patras' average indices demonstrate relatively high standard deviations the above finding cannot be conclusive. In order to further assess the above results, one-way ANOVA of the average *h*-index (h_{aves}) and the average number of publications per

Table 2 Time-related and time-averaged bibliometrics calculated for all chemical engineering departments in department level

Index	Athens	Thessaloniki	Patras	MIT
ra_{ave}	24 (7)	**25** (7)	**25** (9)	27 (14)
ra_{m}	24	**25**	**25**	25
pry_{ave}	19 (7)	19 (8)	**22** (10)	25 (12)
pry_{ave10}	9 (2)	9 (3)	**10** (2)	10 (1)
pry_{m}	19	18	**22**	25
pry_{m10}	**10**	**10**	**10**	11
Py_{ave}	2.6 (1.6)	2.6 (1.8)	**3.2** (2.0)	7.4 (5.9)
Py_{ave10}	3.0 (1.9)	3.8 (3.0)	**4.1** (3.1)	10.9 (10.6)
Py_{m}	2.2	2.5	**2.7**	5.4
Py_{m10}	2.6	2.8	**3.4**	8.4

Numbers in bold font indicate the highest value among the Greek departments in each row; Index "10" at the symbols indicate that the bibliometric index was calculated considering the scientific output of only the last 10 years (2004–2014); Numbers in brackets denote the standard deviation

academic in total (P_{ave}) was also performed, which showed that from a statistical point of view the above mean values for the three Greek departments do not differ significantly from each other.

Table 3 Aggregate bibliometrics calculated for all chemical engineering departments in academic rank level considering the complete research profile of all academics

Index	Athens	Thessaloniki	Patras	MIT
Lecturers				
n_l	**5**	**5**	3	
P_l	**176**	111	19	
$P_{ave\text{-}l}$	**35.2**	22.2	6.3	
$C_{s\text{-}l}$	**2,612**	2,314	194	
$C_{aves\text{-}l}$	14.8	**20.8**	10.2	
$h_{aves\text{-}l}$	**12.0** (4.8)	9.8 (7.7)	3.7 (2.9)	
$h_{ms\text{-}l}$	**13.0**	6.0	2.0	
$g_{aves\text{-}l}$	**20.2** (8.2)	17.8 (12.1)	7.0 (3.5)	
$g_{ms\text{-}l}$	**23.0**	11.0	5.0	
Assistant professors				
n_{assi}	**9**	6	7	9
P_{assi}	**336**	232	255	270
$P_{ave\text{-}assi}$	37.3	**38.7**	36.4	30.0
$C_{s\text{-}assi}$	**6,616**	4,660	3,146	10,816
$C_{aves\text{-}assi}$	19.7	**20.1**	12.3	40.1
$h_{aves\text{-}assi}$	11.7 (7.9)	**13.3** (5.8)	11.7 (4.2)	12.8 (9.0)
$h_{ms\text{-}assi}$	12.0	**13.5**	12.0	11.0
$g_{aves\text{-}assi}$	21.8 (14.4)	**24.8** (12.3)	18.6 (8.0)	28.7 (19.9)
$g_{ms\text{-}assi}$	17.0	**23.5**	19.0	21.0
Associate professors				
n_{asso}	**13**	9	3	4
P_{asso}	**644**	478	186	374
$P_{ave\text{-}asso}$	49.5	53.1	**62.0**	93.5
$C_{s\text{-}asso}$	**9,275**	8,126	6,663	17,003
$C_{aves\text{-}asso}$	14.4	17.0	**35.8**	45.5
$h_{aves\text{-}asso}$	14.1 (6.7)	15.6 (5.6)	**25.3** (7.6)	25.3 (15.5)
$h_{ms\text{-}asso}$	13.0	14.0	**22.0**	23.5
$g_{aves\text{-}asso}$	23.0 (10.0)	26.8 (11.6)	**44.3** (15.9)	57.5 (31.0)
$g_{ms\text{-}asso}$	22.0	25.0	**40.0**	58.0
Professors				
n_p	**45**	14	17	25
P_p	**3,307**	1,432	2,113	7,218
$P_{ave\text{-}p}$	73.5	102.3	**124.3**	288.7
$C_{s\text{-}p}$	**55,865**	24,595	53,715	298,023
$C_{aves\text{-}p}$	16.9	17.2	**25.4**	41.3
$h_{aves\text{-}p}$	18.3 (8.0)	21.5 (9.1)	**27.6** (13.0)	49.4 (26.6)
$h_{ms\text{-}p}$	19.0	19.5	**25.0**	39.0
$g_{aves\text{-}p}$	29.6 (12.8)	34.6 (14.6)	**46.0** (22.2)	86.0 (48.1)
$g_{ms\text{-}p}$	30.0	31.0	**41.0**	76.0

Numbers in bold font indicate the highest value among the Greek departments 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

Although the average bibliometrics of Athens and Thessaloniki are comparable, it is worth noting that Thessaloniki exhibits marginally higher values in all indices than Athens. The above finding is of great interest, since Thessaloniki department hosts considerable smaller faculty size (34 vs 72) and operates substantially less years than Athens.

The above is also enhanced by the results of Table 2, which show that the Patras' annual scientific productivity per academic (Py_{ave}) is higher (3.2 publications) than the corresponding one of Athens and Thessaloniki (2.6 publications).

Inspection of the data of Table 2, leads to interesting findings regarding the research age and the productive years of the academics hosting the chemical engineering departments. Despite the differences in the faculty size, the average research age for all departments is the same (i.e., 24–25 years), meaning that the faculties hosting the three departments feature similar average career lengths. In parallel, the average productive years (pry_{ave}) are slightly higher for the faculty of the Patras' department (22 years) compared to the other two departments (19 years), while another important observation is that in Patras this value is comparable to the one of the average research age. In fact the ratio of the average

Table 4 Time-related and time-averaged bibliometrics calculated for all chemical engineering departments in academic rank level considering the complete research profile of all academics

Index	Athens	Thessaloniki	Patras	MIT
Lecturers				
$ra_{ave\text{-}l}$	**15** (4)	**15** (6)	14 (8)	
$ra_{m\text{-}l}$	13	**14**	10	
$pry_{ave\text{-}l}$	**14** (3)	8 (4)	4 (3)	
$pry_{m\text{-}l}$	**12**	10	3	
$Py_{ave\text{-}l}$	**2.6** (1.6)	1.9 (1.8)	0.7 (0.9)	
$Py_{m\text{-}l}$	**1.9**	1.5	0.3	
Assistant professors				
$ra_{ave\text{-}assi}$	19 (3)	**24** (6)	16 (4)	10 (4)
$ra_{m\text{-}assi}$	19	**25**	15	8
$pry_{ave\text{-}assi}$	12 (8)	**14** (3)	13 (2)	10 (3)
$pry_{m\text{-}assi}$	**16**	15	12	8
$Py_{ave\text{-}assi}$	1.9 (1.4)	1.8 (1.4)	**2.4** (0.8)	3.1 (1.2)
$Py_{m\text{-}assi}$	1.9	1.5	**2.1**	3.5
Associate professors				
$ra_{ave\text{-}asso}$	19 (3)	**22** (5)	**22** (5)	22 (17)
$ra_{m\text{-}asso}$	20	**22**	21	15
$pry_{ave\text{-}asso}$	16 (3)	17 (2)	**21** (4)	17 (7)
$pry_{m\text{-}asso}$	16	17	**21**	15
$Py_{ave\text{-}asso}$	2.7 (1.9)	2.6 (2.4)	**2.9** (0.3)	5.8 (4.2)
$Py_{m\text{-}asso}$	1.7	1.8	**2.9**	5.4
Professors				
$ra_{ave\text{-}p}$	28 (6)	**31** (5)	**31** (6)	33 (11)
$ra_{m\text{-}p}$	29	**32**	**32**	36
$pry_{ave\text{-}p}$	22 (6)	25 (6)	**28** (6)	32 (9)
$pry_{m\text{-}p}$	22	24	**28**	34
$Py_{ave\text{-}p}$	2.7 (1.5)	3.3 (1.5)	**4.1** (2.2)	9.2 (6.4)
$Py_{m\text{-}p}$	2.3	3.0	**3.7**	8.1

Numbers in bold font indicate the highest value among the Greek departments 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

productive years to the average total research age is 88 %, meaning that academics in Patras exhibit considerably less inactive years through their total career compared to the other departments.

Comparison of the Greek chemical engineering departments in academic rank level

Bibliometrics calculated as a function of the academic rank for all departments studied (Greek and MIT) are presented in Table 3. Athens holds the first position in all ranks when values are not averaged (P and C_s), since it hosts the most numerous academics not only in total, but in each rank as well (Lecturers are equal to that of Thessaloniki).

In other respects, and considering the complete research profile of academics, the ranking seems to vary with the academic rank. More specifically, Athens hosts Lecturers of better research profile, with all indices (average and median) higher than the respective ones of the Thessaloniki and Patras departments. Thessaloniki department follows with slightly lower values, while it is also worth noting that in the case of Lecturers, the Patras department exhibits extremely low values in all indices. The only observed variation from the above pattern concerns the average number of citations per publication per lecturer ($C_{\text{aves-l}}$), where Thessaloniki displays higher value than that of Athens (20.8 vs 14.8).

Inspecting the indices of the Assistant Professors, the ranking is altered. Thessaloniki demonstrates slightly higher values in all indices than the other two departments which seem to share the second place with comparable indices. On the other hand, both Associate Professors and Professors of Patras department seem of much better research activity (Table 3), since all indices are considerably higher compared to the ones of the other two departments. The research distinction of Patras' academics of the two highest ranks explains its eminence in department level.

Finally, it should be noted that Thessaloniki exhibits higher values than Athens in the case of both Associate Professors and Professors, regardless its smaller faculty size in both ranks. Although most hybrid indices are comparable, a very interesting variation concerns the average number of publications per Professor ($P_{\text{ave-p}}$). Professors in Thessaloniki, though fourteen in number, appear remarkably more productive compared to the Professors in Athens department ($P_{\text{ave-p}} = 102.3$ vs 73.5).

The above ranking of the departments depending on the academic rank is partially also reflected in the data of Table 4, which shows the time-related and time-averaged bibliometrics in academic rank level. Athens seems to host Lecturers with the highest annual productivity in average ($\text{Py}_{\text{ave-l}}$), while Patras department hosts academics of the highest annual productivity in average belonging to the other three academic ranks.

In parallel, all departments host academics of comparable research ages (in average) for the various ranks (Table 4). However, a variation is observed in the case of the Assistant Professors, where the average research age is considerably higher in Thessaloniki, with academics in this rank initiating their research activity very early.

In addition, interesting observations can also be made for the various ranks regarding the actual research years (pry_{ave}). In the case of Lecturers, Athens department exhibits much higher average productive years ($\text{pry}_{\text{ave-l}}$) than the other two departments, with a ratio of the average productive years to the average total research age more than 93 %. Assistant Professors demonstrate similar $\text{pry}_{\text{ave-assi}}$ in all departments, but the ratio of the average productive years to the average total research age is considerably high in the case of Patras ($\sim$81 %). Finally, the Patras' corresponding index for both Associate Professors and Professors is slightly higher than the rest of the chemical engineering departments,

while the ratio of the average productive years to the average total research age is comparable in all departments.

Comparing the bibliometrics of the various academic ranks in each university separately, interesting conclusions can also be extracted about the research quality in rank level for each department. Figure 1 illustrates the average *h*-index of each academic rank for all Greek chemical engineering departments. One can readily observe that in all Greek chemical engineering departments there is a consistency regarding the research quality among the different ranks, namely academics of higher ranks have more improved and acknowledged scientific profile. One deviation is discernible in the case of Athens, where Lecturers exhibit slightly more improved research experience than Assistant Professors.

In the same respect, from Table 4, it is evident that only in the case of Patras there is a consistency regarding the average research age of academics of the various ranks, where academics of higher ranks have longer careers.

Standard deviations of the hybrid bibliometric indices (*h*- and *g*- index) (Table 3) in conjunction with a comparison between the average and median values, can give valuable information about the heterogeneity in each rank of the departments studied, regarding the research profile of academics of the same rank. A first observation is that the standard deviation of the indices of the Lecturers is considerably high in Thessaloniki and Patras, indicating that dispersion and heterogeneity among the indices of academics of this rank is remarkably high in these two departments. In the case of Assistant Professors, the Athens department exhibits relatively high standard deviations for the hybrid indices, although the average values are close to the median ones. The opposite appears to be valid for Associate Professors and Professors in all departments. For both ranks average *h*- and *g*- indices exhibit low standard deviation, with the median values close to the average ones in most cases, indicative of relatively high homogeneity (similar scientific profiles) in these ranks.

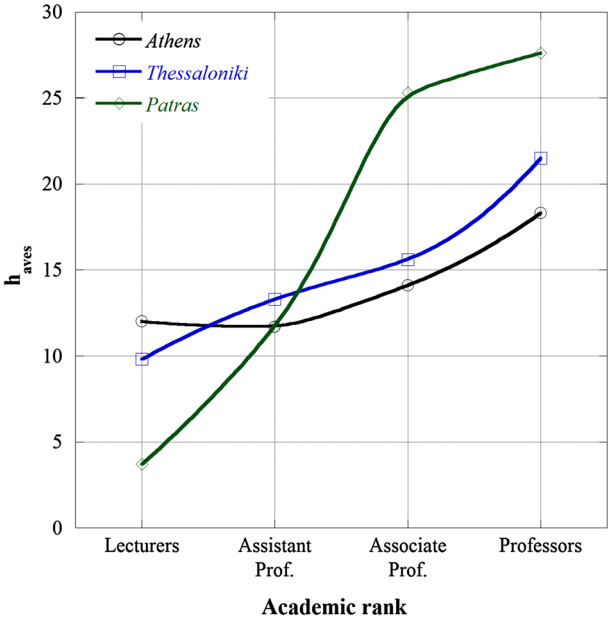

Fig. 1 *h*-index (h_{aves}) of the various academic ranks for all Greek universities studied

The above observations are also supported by the data of Table 4 and mainly by the standard deviations of the Py_{ave}. In the case of the Lecturers, standard deviations are high, while in the case of Patras it is higher even than the average value. In the same respect, for the rest of the academic ranks similar inferences can also be made as previously discussed.

Research quality of faculty in Greek chemical engineering departments in International context

Bibliometric indices have also been calculated for the top chemical engineering departments in the world (Table 1), according to the QS Ranking (QS 2014), in order to compare them with those of the Greek departments and examine potential variations. From Table 1, it is apparent that the MIT department outnumbers all Greek departments in all bibliometrics. Despite the fact that its faculty size is much smaller than Athens' and comparable to that of Thessaloniki and Patras, the total number of published documents (P) and the total citations (C_s) are impressive. When values are averaged, MIT displays significantly high average number of publications per academic (P_{ave}) and average number of citations per publication (C_{aves}), with the former being double or thrice and the latter almost double the corresponding values of the Greek departments. The same seems to be valid inspecting the h- and g- indices. To test if the average h-index (h_{aves}) of MIT statistically differs significantly from that of the Greek departments one-way ANOVA is also performed (Fig. 2).

The analysis in conjunction with the Tukey's HSD Post-hoc test indicate that MIT's average h-index differs significantly from the h_{aves} of all Greek departments, which is also supported by the data from Table 2. More specifically, academics of MIT seem to be very research productive in terms of annual papers published in average (7.4 papers) considering the complete career of all academics, while the respective value is almost 2.5–3.0 times lower in the case of the Greek departments. In addition, the average research age for academics of MIT is 27 years, slightly higher than the ra_{ave} of the Greek departments,

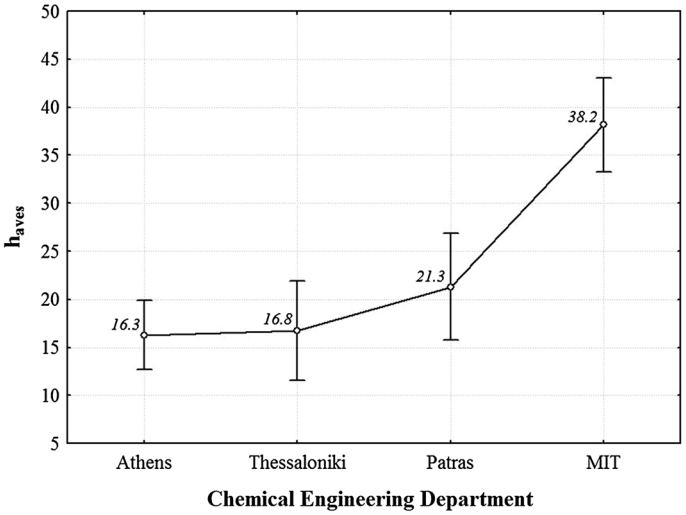

Fig. 2 One-way ANOVA of the h_{aves} for all chemical engineering departments (Greek and MIT); *Vertical bars* denote 0.95 confidence intervals

while the ratio of the average productive years (pry_{ave}) to the average total research age is 93 %, meaning that the inactive years through their total career are negligible.

From Table 3, one can see that although the number of the Assistant Professors hosting the MIT is larger than the one of the Greek departments (but equal to that of Athens), the total publications (P_{assi}) are less than that of Athens and comparable with the ones of the other two Greek departments. Moreover, their average value ($P_{ave\text{-}assi}$) is lower than the respective one of all Greek departments. However, the above is not valid when the citations of the published papers are considered for comparison purposes. Both total ($C_{s\text{-}assi}$) and average citations per publication ($C_{aves\text{-}assi}$) are significantly higher than the ones of the Greek departments, implying that the impact of the published documents is much greater despite their smaller number. As a result, Assistant Professors in MIT exhibit better hybrid indices.

The findings are similar when comparing the research activity of Associate Professors between the MIT and the Greek departments. Due to their small number (n_{asso}), the total publications (P_{asso}) are less than that of Athens and Thessaloniki. Nevertheless, when the value is averaged, superiority of MIT is evident ($P_{ave\text{-}asso} = 93.5$). In the same respect, both total ($C_{s\text{-}asso}$) and average citations per publication ($C_{aves\text{-}asso}$) are significantly higher than the ones of the Greek departments. Consequently, the average h-index is higher than that of Athens and Thessaloniki, but it is surprisingly equal to that of Patras. However, when the highly cited articles are considered (g_{aves}) dominance of MIT is undisputable. Finally, Professors in MIT present outstanding bibliometrics with extremely large number of citations, as in the other ranks, indicative of the significance of the conducted research.

In parallel, according to Table 4, academics of MIT appear much more productive than the Greek departments, with higher annual publications per academic for all ranks. In addition, in MIT the average research ages are comparable with those of the Greek departments in the case of Associate Professors and Professors. However, it should be mentioned that the MIT academics which presently serve as Assistant Professors have considerably shorter research experience ($ra_{ave\text{-}assi} = 10$ years) than academics of the same rank in the Greek departments. Finally, the ratio of the average productive years (pry_{ave}) to the average total research age varies with the academic rank. The above ratio is 100 % for the Assistant Professors, 77 % for the Associate Professors, which is equal or lower than the corresponding ratio in the Greek departments, and 97 % for the Professors.

Research performance during the last decade

Comparison in department level

According to Table 1, the ranking in department level is the same as previously described when considering the complete research profile of all academics. Athens department is at the helm of the research activity of the last decade in terms of total publications (P_{10}) and citations (C_{s10}). However, when the values are averaged, Patras occupies the first place in all bibliometrics of the last decade, while Thessaloniki displays comparable, yet slightly higher, indices to that of Athens, as also supported by the ANOVA of the h_{aves10} (not shown here). Bibliometrics of the MIT department of the last decade are very impressive and by far higher than those of the Greek departments, a finding also supported by the ANOVA of the h_{aves10} of all chemical engineering departments (not shown here).

The above findings are also enhanced by the time-related and time-averaged bibliometrics of the last decade (Table 2). First of all, the average productivity of the last decade (Py_{ave10}) is higher than the total average one (Py_{ave}) in all departments. Other than that, the

Patras department exhibits the largest annual number of publications per academic among the Greek departments, while MIT's respective productivity is again remarkably high. It should also be noted, that during the period 2004–2014 (end of June) the departments of Patras and MIT have ten (10) research active years, with at least one paper published per year during this period, while at the same time the Athens and Thessaloniki departments display nine (9) actual productive years.

Table 5, which presents the percentage of published documents and citations that correspond to the period 2004–2014 shows that in Athens and Patras the number of published documents the last decade (P_{10}) is about half (51.3 and 49.7 % respectively) of the total when no time limit is considered (P). In the case of Thessaloniki the above ratio is higher up to 60.6 %. Similarly, citations of these documents (C_{s10}) correspond to less than 38 % of the total citations (C_s) for Athens and Patras, while in Thessaloniki the above fraction is 46.8 %, meaning that total citations of the papers published through the complete career of its academics are equally shared in the periods before and after 2004. In the same respect, 55.5 % of the total documents in MIT are published after 2004, while citations of these papers are nearly half of the total ones (45.2 %).

Comparison in rank level

Last decade bibliometrics are also calculated for each rank and are presented in Tables 6 and 7. It is evident that the department ranking is academic rank dependant and in few cases different from the one described when the complete research profile of the academics was taken into account. More specifically, Lecturers of Athens present a much higher research activity the last decade ($P_{\text{ave-l10}}$) compared to the other two Greek departments, which is also supported by its annual productivity rate per Lecturer ($\text{Py}_{\text{ave-l10}} = 2.6$). On the other hand, papers published by the Lecturers in Thessaloniki are of higher scientific impact, since they display the highest citations per document in the studied period ($C_{\text{aves-l10}}$). As a result of the above, Lecturers of Athens dominate regarding the average hybrid indices (h- and g- index). Lecturers in Patras exhibit a considerably low research activity during the last decade, with very low values in most indices, while the annual publication rate per Lecturer is merely 0.6.

In the case of the Assistant Professors, Thessaloniki maintains the first place regarding the impact of the published documents ($C_{\text{aves-assi10}}$), but superiority concerning the

Table 5 Percentage of total published documents and citations that correspond to last decade

	Athens		Thessaloniki		Patras		MIT	
	% *P*	% *C*	% *P*	% *C*	% *P*	% *C*	% *P*	% *C*
Lecturers	78.2	63.9	68.8	56.6	83.3	85.9		
Assistant prof.	53.0	44.2	65.8	62.9	78.4	66.3	94.4	90.2
Associate prof.	65.6	48.2	64.4	48.8	57.1	40.7	75.1	66.2
Professors	48.9	38.6	54.3	44.1	46.7	33.8	53.4	41.1
Department	51.3	35.1	60.6	46.8	49.7	37.5	55.5	45.2

% *P* is calculated as $(P_{10}/P)*100$

% *C* is calculated as $(C_{s10}/C_s)*100$

Table 6 Aggregate bibliometrics calculated for all chemical engineering departments in academic rank level considering the scientific output of only the last decade

Index	Athens	Thessaloniki	Patras	MIT
Lecturers				
P_{l10}	**137**	101	18	
$P_{ave\text{-}l10}$	**27.4**	20.2	6.0	
$C_{s\text{-}l10}$	1,474	**2,097**	183	
$C_{aves\text{-}l10}$	10.8	**20.8**	10.2	
$h_{aves\text{-}l10}$	**9.2** (4.4)	8.8 (8.6)	3.3 (3.2)	
$h_{ms\text{-}l10}$	**8.0**	4.0	2.0	
$g_{aves\text{-}l10}$	**15.2** (5.5)	14.8 (14.9)	6.3 (4.2)	
$g_{ms\text{-}l10}$	**15.0**	7.0	5.0	
Assistant professors				
P_{assi10}	194	166	**198**	253
$P_{ave\text{-}assi10}$	21.6	27.7	**28.3**	28.1
$C_{s\text{-}assi10}$	2,218	**2,631**	1,865	9,787
$C_{aves\text{-}assi10}$	11.4	**15.8**	9.4	38.7
$h_{aves\text{-}assi10}$	7.0 (5.5)	**9.8** (4.4)	8.9 (4.2)	11.6 (8.3)
$h_{ms\text{-}assi10}$	6.0	**11.5**	7.0	10.0
$g_{aves\text{-}assi10}$	13.0 (7.3)	**19.0** (8.1)	14.1 (5.6)	26.8 (19.7)
$g_{ms\text{-}assi10}$	14.0	**21.5**	15.0	19.0
Associate professors				
P_{asso10}	**433**	331	104	311
$P_{ave\text{-}asso10}$	33.3	**36.8**	34.7	77.8
$C_{s\text{-}asso10}$	**4,558**	3,517	2,869	13,331
$C_{aves\text{-}asso10}$	10.5	10.6	**27.6**	42.9
$h_{aves\text{-}asso10}$	9.1 (5.5)	10.4 (3.5)	**15.7** (8.6)	21.0 (15.6)
$h_{ms\text{-}asso10}$	9.0	12.0	**14.0**	20.0
$g_{aves\text{-}asso10}$	15.3 (8.0)	17.8 (7.0)	**27.3** (16.3)	48.3 (32.2)
$g_{ms\text{-}asso10}$	16.0	17.0	**24.0**	51.5
Professors				
P_{p10}	**1,525**	767	960	3,802
$P_{ave\text{-}p10}$	33.9	54.8	**56.5**	152.1
$C_{s\text{-}p10}$	17,842	10,344	**18,958**	124,094
$C_{aves\text{-}p10}$	11.7	13.5	**19.7**	32.6
$h_{aves\text{-}p10}$	10.0 (4.6)	14.2 (7.5)	**16.2** (9.6)	31.5 (19.7)
$h_{ms\text{-}p10}$	10.0	**13.0**	12.0	29.0
$g_{aves\text{-}p10}$	17.4 (7.7)	22.5 (11.8)	**26.6** (17.5)	55.9 (35.2)
$g_{ms\text{-}p10}$	17.0	21.0	**22.0**	50.0

Numbers in bold font indicate the highest value among the *Greek* departments in each row; Indices at symbols of bibliometrics denote: *l* lecturers, *assi* assistant professors, *asso* associate professors and *p* professors; Index "10" at the symbols indicate that the bibliometric index was calculated considering the scientific output of only the last 10 years (2004–2014); Numbers in brackets denote the standard deviation

productivity is passed to Patras department ($P_{ave\text{-}assi10}$ and $Py_{ave\text{-}assi10}$). Finally, the hybrid indices of the Assistant Professors in Thessaloniki are higher than the ones of the other two departments which display comparable values.

In addition, regarding the Associate Professors, although all departments exhibit comparable productivity ($P_{ave\text{-}asso10}$ and $Py_{ave\text{-}asso10}$) with Thessaloniki slightly being distinguished, dominance of Patras over all other bibliometrics, impact and hybrid, is evident. Finally, Professors in Patras appear of extremely intense and significant research

Table 7 Time-related and time-averaged bibliometrics calculated for all chemical engineering departments in academic rank level considering the scientific output of only the last decade

Index	Athens	Thessaloniki	Patras	MIT
Lecturers				
$pry_{ave\text{-}l10}$	**10** (1)	7 (5)	4 (4)	
$pry_{m\text{-}l10}$	**10**	9	3	
$Py_{ave\text{-}l10}$	**2.6** (1.4)	1.9 (1.9)	0.6 (0.7)	
$Py_{m\text{-}l10}$	**2.3**	1.0	0.3	
Assistant professors				
$pry_{ave\text{-}assi10}$	7 (4)	8 (3)	**9** (1)	8 (2)
$pry_{m\text{-}assi10}$	7	9	**10**	8
$Py_{ave\text{-}assi10}$	2.1 (1.9)	2.6 (1.8)	**2.7** (1.0)	2.7 (1.7)
$Py_{m\text{-}assi10}$	1.8	2.5	**2.6**	2.3
Associate professors				
$pry_{ave\text{-}asso10}$	9 (2)	9 (1)	**10** (1)	9 (2)
$pry_{m\text{-}asso10}$	**10**	9	**10**	10
$Py_{ave\text{-}asso10}$	3.2 (2.1)	**3.5** (3.2)	3.3 (0.9)	7.4 (6.7)
$Py_{m\text{-}asso10}$	2.5	2.2	**3.6**	5.5
Professors				
$pry_{ave\text{-}p10}$	9 (2)	10 (2)	**11** (1)	11 (1)
$pry_{m\text{-}p10}$	10	10	**11**	11
$Py_{ave\text{-}p10}$	3.2 (1.8)	5.2 (3.0)	**5.4** (3.4)	14.5 (11.2)
$Py_{m\text{-}p10}$	2.7	4.7	**4.9**	12.0

Numbers in bold font indicate the highest value among the *Greek* departments in each row; Indices at symbols of bibliometrics denote: *l* lecturers, *assi* assistant professors, *asso* associate professors and *p* professors; Index "10" at the symbols indicate that the bibliometric index was calculated considering the scientific output of only the last 10 years (2004–2014); Numbers in brackets denote the standard deviation

activity during the period 2004–2014 displaying remarkable values in all bibliometrics. In parallel, Thessaloniki holds the second place, while Athens follows with much lower average values.

It is also worth mentioning that academics of all ranks in MIT department display exceptional recent scientific work, since their indices are in some cases even three or four times higher than the corresponding ones of the same rank in the Greek departments (e.g. $C_{aves\text{-}asso10}$ and $h_{aves\text{-}p10}$). The only variation observed concerns the Assistant Professors in MIT where the $P_{ave\text{-}assi10}$ and $Py_{ave\text{-}assi10}$ are comparable with that of Thessaloniki and Patras departments, which however cannot distort the total image of the recent research activity of the Assistant Professors in MIT.

Finally, data from Table 7 indicate that the actual research years during the last decade are comparable for all departments in the case of Assistant and Associate Professors. Yet, Lecturers in Athens appear more scientifically active among the Greek departments, while Professors in Patras and MIT display the maximum allowed value (11 years).

Examination of Table 5 can also shed light on the last decade scientific activity for the various ranks, taking into account the present rank of each researcher. It is evident that both the number of published documents and their citations when they are calculated for the period 2004–2014 (P_{l10} and $C_{s\text{-}l10}$, respectively) constitute a significant percentage of the total ones (69–83 and 56–86 % respectively) in the case of Lecturers of all Greek departments, which is expected since this period covers almost their entire, so far, academic career (Kazakis 2014). Moving up to the academic hierarchy these percentages gradually decline, since for academics of higher rank, activity before 2004 is stronger and of more impact. Several variations are observed, e.g. Associate Professors in Athens

exhibit significantly higher percentage in both documents and citations than Assistant Professors.

In the case of MIT, the last decade number of published documents and their citations are higher than the relevant ones of the Greek departments in all ranks. Remarkable are also the percentages of the Assistant Professors in MIT, whose research activity in the last decade corresponds to more than 94 % of their total one through their complete career.

Temporal evaluation of research productivity

In order to gain an insight into the temporal progress of the research productivity, the number of publications for the last fourteen and a half years is considered on an annual basis. For this purpose the scientific profiles of only the currently Professors were taken into account, since it is more probable that these academics were at the same department during this period (Fig. 3).

For the Thessaloniki and Patras departments, research productivity continuously increased until 2008 and then the number of published documents remained either constant or started to descend up to date. The same trend after 2008 is also observed for Athens, but in this department an abrupt decline in the published documents also took place in 2006. That means that the last five-six years the scientific productivity is in a predicament.

On the other hand, a similar conclusion cannot be extracted for the MIT, since the temporal progress of the publications on annual basis follows a more complex pattern. Of course, the drop observed in 2014 in all departments cannot be evaluated since publications refer only to the first half of the year.

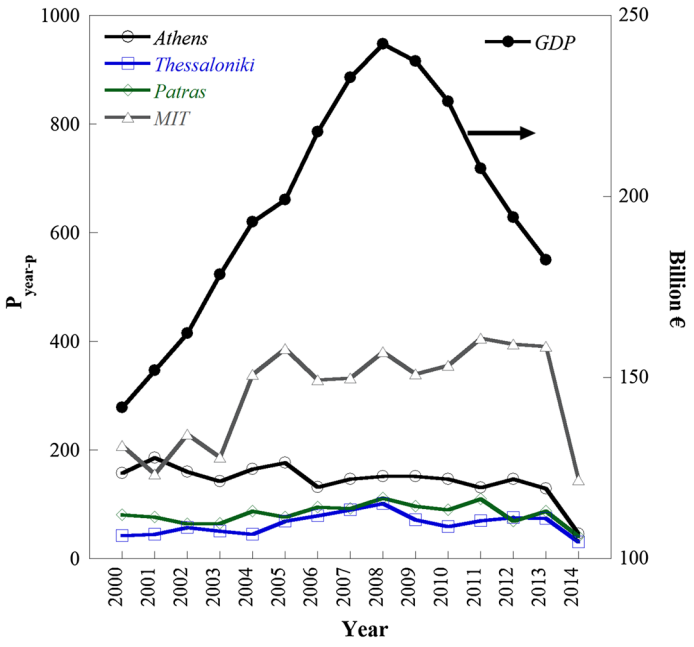

Fig. 3 Annual number of published documents by academics which presently are Professors for all chemical engineering departments studied (Greek and MIT) (*left vertical axis*) and growth rate of the gross domestic product (*GDP*) in Greece (*right vertical axis*) (EL.STAT. 2013)

Gender distribution in the chemical engineering departments

Besides all the bibliometrics which directly refer to the research activity of all academics, additional statistical information which could implicitly be connected to the policy of the chemical engineering departments adopted is the gender distribution (Fig. 4). It is evident that female academics hosting the Greek chemical engineering departments constitute only a small minority of the total academics. Athens and Thessaloniki host the most female academics in a percentage of about 30 %. It is worth noting that in the Patras department the above percentage is merely 3.3 %, which in fact corresponds to just one female academic out of thirty in total. The above female academic in the Patras department serves currently as Professor, while the rest of the ranks are entirely composed of male academics. A general pattern regarding the gender distribution among the various academic ranks is not observed, since in Athens, percentage of females is higher in the Professors, while in Thessaloniki, female Lecturers are more in percentage compared to the other three ranks. The above gender distribution is also repeated in the MIT with only 13.2 % of the academics being female, while the higher percentage of female academics corresponds to the Associate Professors.

Discussion and conclusions

In the present study the evaluation of the research quality and activity of the current faculty of the three Greek chemical engineering departments is conducted by means of bibliometrics. For this purpose numerous widely accepted bibliometrics along with several time-averaged and time-related indices are recruited. It should be noted that such a bibliometric

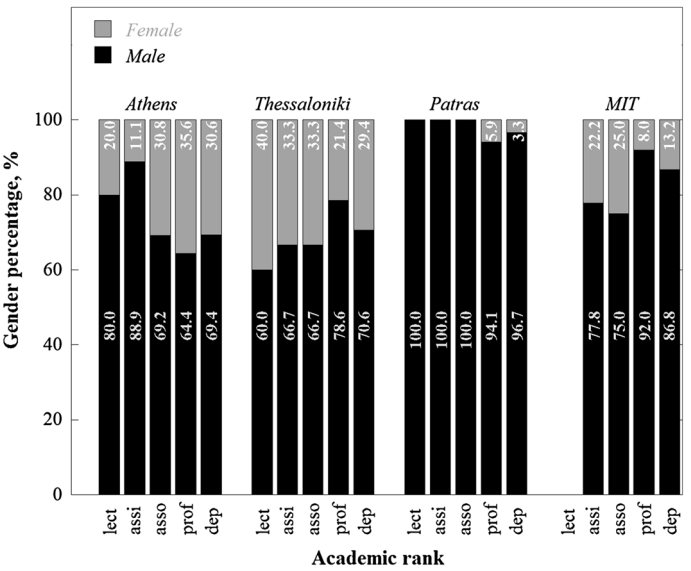

Fig. 4 Gender distribution (male or female academics) in all chemical engineering departments studied (Greek and MIT) in academic rank and department level; Abbreviations at the x-axis denote: *lect* lecturers, *assi* assistant professors, *asso* associate professors, *prof* professors and *dep* department

study is based on the assumption that scientists who have to say something important, publish their findings in the open, international journal literature, which creates a "bibliometrically limited view of a complex reality" (Van Raan 2005). However, it is evident that inspired scientists in most cases (e.g. natural sciences, medical fields, engineering) try to publish in the better and, if possible, the best journals (Van Raan 2005).

Current faculty of Patras department displays the highest values in all bibliometrics when the complete research profile of all academics is taken into account. The findings are indicative of the more productive and scientifically significant research career of Patras' academics. In addition, Athens and Thessaloniki share the second place with comparable average bibliometrics, yet, with the latter exhibiting marginally higher values in all indices than the former. The findings of the present work are in agreement with those of Lazaridis (2010) who also compared the same departments using the mean *h*-index.

The above findings support the general idea that the quality of academics as researchers is not dictated by the age and size of their institution. This is in agreement with the findings of Kazakis (2014), who found that departments relatively newly-founded and of small faculty size may display remarkable bibliometrics and of Slyder et al. (2011), who concluded that the impact of the published documents was not influenced by an author's institutional affiliation. Similarly, according to Usher (2012) the relationship between institutional characteristics and *h*-index is not straightforward. In fact, the relationship between *h*-index and institution age and size may be negative in many cases, with new and small departments exhibiting outstanding research quality.

The average research age is comparable for all Greek departments, but Athens and Thessaloniki display a considerable number of inactive years, where no paper was published. The above could be attributed to several reasons. Since the complete research profile of all academics is considered, it is almost certain that many of them were not appointed to a university department directly after acquiring their doctorate. A period of research stagnancy is most likely to exist for a considerable number of them, while they may be involved into non-academic/research activities (e.g. industry) for livelihood purposes. In addition, according to the former Greek legislation, academics of the first rank, i.e., Lecturers, are not allowed to supervise doctoral students and thus they are short of available hands who would conduct most of the experimental work during research. Moreover, being in the first steps of their academic career, Lecturers and Assistant Professors, in some cases, are not considered eligible to coordinate large-scale research projects (co-)funded by the European Commission due to their little experience and low reputation. As a result, they are expected to continue/conduct research with their own resources, which ultimately may lead to counter-productive years unless they seek for collaboration with academics of higher rank in the same department or with other institutions.

The bibliometric ranking of the studied departments varies with the academic rank, but the most remarkable finding is the low quality of Lecturers in Thessaloniki and Patras. A quick inspection of the available CVs of the Lecturers leads to the conclusion that they are divided into two-speed researchers with different research activity. The above can be justified considering the Greek legislation dictating the university operation the last decades. The legislation 1268/1982 (1982) gave the opportunity to, at that time, laboratory and/or teaching assistants to become Lecturers with tenure as long as they had a doctorate. One decade later the legislation 2083/1992 (1992) gave also the chance to non-tenure Lecturers and Assistant Professors to become tenure as long as they serve at least 3 years at this rank. Of course the above legislative adjustments are not valid up to now and Lecturers are appointed with similar to the other ranks procedures. Due to the above, departments

may still consist of tenured and non-tenured Lecturers, with the majority of the former being entirely engaged into their teaching obligations and displaying negligible research activity, thus negatively influencing the average indices of this rank and the overall ones as well.

Bibliometrics in rank level are also indicative of the "academic health" of each department. Contrary to the Greek medical schools (Kazakis et al. 2014) and the Greek civil engineering departments (Kazakis 2014), the Greek chemical engineering departments exhibit a consistency regarding the research quality among the different ranks, with academics of higher ranks exhibiting more improved and acknowledged scientific profile.

The above pattern is in most cases the expected (and the meritocracy-linked) one for several reasons. It is accepted that academics of higher rank have more experience and personal competencies (Abramo et al. 2011), while the accumulated knowledge and incessant activity makes them experts on their field (Puuska 2010). In addition, more senior academics have larger professional network, giving them access to human resources and equipment necessary to conduct research in every scientific field (Abramo et al. 2011). The above is also enhanced by the fact that academics of higher ranks supervise Ph.D. or M.S. theses and recruit more under-graduate students and thus have more junior "researchers" available for the time and energy-consuming experiments. In parallel, when research productivity is measured in terms of *h*- and *g*- indices, senior academics have greater impact even if they do not publish more articles in high-rank journals than their less senior colleagues (Mishra and Smyth 2013), because of their supervising role in the published research (Costas and Bordons 2011). Finally, it is also evident that more senior academics have lighter teaching loads than academics of low ranks, who are engaged in the teaching process to a greater extent and spend more time preparing notes and/or teaching material (Blackburn et al. 1978; Talib 2002).

Although a consistency between h_{aves} and academic rank may exist, however, in the case of Patras, h_{aves} is increased with extraordinarily high rate when moving to higher academic degrees compared to the other two departments. In addition, several variations in the research quality of academics of the same rank among the various departments are also observed. The above constitute further evidence that there are no common established standards in the hiring and/or promotion policies in Greek universities and they are not explicitly dictated by any legislation, as already found for the Greek medical schools (Kazakis et al. 2014) and the Greek civil engineering departments (Kazakis 2014).

According to the findings, most academic ranks feature relatively high homogeneity in all departments. The above means that in the Greek chemical engineering departments discriminatory phenomena, such as nepotism, during individual evaluation for hiring or promotion are negligible. However, based on the CVs of all academics and their personal research profile, the phenomenon of inbreeding, namely favouritism towards internal candidates in case on new hirings, seems to be very acute in the Greek chemical engineering departments. This has also been observed by Lazaridis (2010), who ascribed the bad research performance of the Athens chemical engineering department to this phenomenon.

The comparison between the Greek chemical engineering departments and the MIT chemical engineering department showed that, despite its small faculty size, the superiority of MIT is evident, with stunning indices in some cases. Bibliometrics in rank level also support the dominance of MIT in all ranks except from the Assistant Professors, who exhibit lower productivity, yet of higher impact, than those of the Greek departments. This can probably be attributed to the fact that this rank is the first one in the academic hierarchy of the American system and thus academics of this rank have shorter past research activity.

The difference between the research quality of the Greek and MIT faculty can mainly be ascribed to the applied nature of the research conducted in the latter. Although the research areas may be similar, however the level of research is incomparable. In many cases, research in Greek departments is limited to a fundamental basis, while in MIT the main goal is the production of innovative products and/or methods in many application areas. Of course the level of research is also proportional to the funding and the available equipment, which would support the research results. In this section, Greek departments definitely lag far behind MIT.

When bibliometrics are calculated using a common time basis, the ranking of the departments is similar as the one when considering the complete research profile of all academics. Patras department appears to be more scientifically active the last decade, while Thessaloniki displays slightly higher indices than Athens. Of course, MIT exhibits an outstanding research performance during the studied time period. The above ranking is in accordance with the recent ranking (2014) by the QS World University Rankings regarding the academic reputation for the chemical engineering departments in a global scale, which gives a measure of where the best work is currently taking place within a field of expertise.

In the same respect, it is revealed that moving up to the academic hierarchy, the percentage of the publications and citations that refer to the last decade gradually declines. In higher ranks the productivity rate decreases and previous work plays more determinant role for the bibliometrics formulation. The same trend was also found for the civil engineering departments (Kazakis 2014) and constitutes the expected pattern, since senior academics are involved into a range of administrative and leadership functions in an academic department, which might condense the available time for research (Mishra and Smyth 2013).

The propensity witnessed studying the temporal evolution of the research wok is similar in all Greek departments, where productivity, i.e., number of published documents either remained constant or started to descend after 2008. The above complies with the findings of Kazakis (2014) where the same trend was observed in the case of the Greek civil engineering departments and it enhances the argument of Sachini et al. (2013) that this is representative of the research activity in all Greek higher education institutions. The rising course of the research productivity in universities of Greece stopped in 2008–2009, a condition which seems to have its roots in the European economic crisis which onset in 2008. The above is also supported by the data of the growth rate of the gross domestic product (*GDP*) in Greece depicting a considerable reduction of GDP after 2008. As elaborated by Kazakis (2014) the negative impact of the economic crisis on the research performance of the Greek universities was huge. Budget cut of more than 30 % (EUA 2011) hindered the smooth operation of universities and triggered a substantial deceleration of the research activity especially in fields where experimental work is prerequisite for the advancement of science. As such, the chemical engineering was one of the first fields who met significant problems and had to tackle major reductions in both human and financial resources.

Finally, the gender distribution in the various academics ranks of all chemical engineering departments indicate that female academics are merely a minor portion of the total academics in the chemical engineering departments. This unequal distribution of male and female academics has been observed by several investigators (e.g. Abramo et al. 2009; Danell and Hjerm 2013) and it seems that the above is a general trend observed in a European and global scale as well. As Danell and Hjerm (2013) state, although the society is getting better in terms of gender equality, the university system is not necessary following the rest of the society. In parallel, according to the European Union (2013), the

average proportion of female researchers in the EU-27 stood at 33 % in 2009, while it will still take a long time to significantly improve the gender balance in research. In addition, Greece is among the countries in which the gender gap increases, since the number of male researchers has grown at a faster rate over the period 2002–2009.

This could be attributed to the fact that the percentage of women who chose to pursue university education, especially of technical discipline, was considerably small before the 80s, while those who would further continue with postgraduate studies were only minor, resulting in a negligible number of female academic candidates. Even now the female students in the engineering departments of Greece are about 30 % (RCGE 2008) indicative of the male dominance in the related disciplines. In addition, according to ETAN (2000), recruitment and promotion procedures in the higher education are not transparent and do not follow good practice. In most cases the board of examiners is constituted by male academics that prevent the career advancement of female nominees (ETAN 2000).

A connection between the superiority of Patras department and the male dominance among its academics cannot be made. However, numerous studies have reported evidence of considerable productivity differences between male and female scholars, with the former being more productive in various scientific fields (Puuska 2010). Males demonstrate a higher average productivity with respect to that of females for all the performance indicators, but the performance gap seems to reduce with career advancement (Abramo et al. 2009).

In conclusion, bibliometrics, using easily accessible data, is a useful tool which allows the prompt and objective evaluation of at least the research performance among departments of the same discipline, which, however, represents only a fraction of the complete quality of each department. Such rankings are more than desirable, since their goal is not to disparage the departments which do not perform well, but to spur healthy competition and contribute towards the identification and rectification of all the negative aspects both in individual and department level. Consequently, the findings of the present work should provide feedback to the academic community, which should not "let sleeping dogs lie", but should take all appropriate actions to improve and advance the research performance and policy in the intriguing field of chemical engineering in Greece.

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