The impact of scientific career duration on evaluating researchers' scientific productivity: The case of Iran's papers indexed in SCI during 1991-2011

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ABSTRACT
Researchers with different scientific career durations vary in their scientific productivity. Therefore, it is necessary to normalize their publication numbers by their scientific career durations in order to have a more objective comparison among researchers. The present study attempts to verify the impact of scientific career duration on research evaluation using scientometrics method. To do so, it compares Iranian researchers' publication rates in various disciplines covered in the Science Citation Index (SCI) during the period of 1991-2011. The analysis concentrates on those Iranian, who are corresponding authors, with long scientific career durations. The results show that the disciplines significantly vary in their researchers' scientific career durations and their crude number of papers. However, no significant difference was observed in the researchers' publication rates when the comparisons are limited to 21-year SCD researchers, the dominant group of the sample. In other words, the differences observed between many disciplines in their scientific productivity would disappear after normalizing the publication counts by authors' scientific career duration. This implies that comparison among scientists would be reasonable only if they are of the same area of expertise and in similar phases of their scientific lives. It is of special importance to those studies on research assessment that concentrate on a single year or a limited time period.

Keywords: Scientific productivity; Publication rate; Scientific career duration; Scientometrics; Research assessment.

INTRODUCTION

Scientific productivity, defined as the level of scientific production activity, is quantitatively measured using the number of scientific publications in prestigious journals. However, the number of scientific papers varies widely among researchers, depending on individual, social, organizational and discipline-related factors (Shockley, 1957; Ortner 2010). Therefore, the crude publication count cannot be used to provide a realistic evaluation and comparison of scientific productivity of researchers, unless it is normalized by different characteristics of the researchers. Authors' scientific productivity has been the focus of many studies. To obtain more objective results, the studies have attempted to normalize scientific productivity by different measures, including authors' numbers (as reflected in publication per capita) and scientific career duration (represented in publication rate and publication speed). For example, Rubio (1992) investigated scientific productivity of scientists in Social Science and Linguistics in Spanish universities using publication rate and publication per capita. The results showed an increase in the scientific productivity. Wagner-Dobler (1995) examined distribution models of scientific productivity. He believes that comparison among researchers with similar scientific career duration is necessary to accomplish a more objective evaluation. He also shows that publication speed, which has an approximately normal distribution, is a better indicator for measuring scientific capacity compared to crude publication counts.

Scientific career duration (SCD), or "duration of scientific participation" as coined by Gupta and Karisiddappa (1997), is one of the most important factors in determining the level of scholarly productivity (Huber 2001; 2002). Calculated based on the first and last year of a researcher's publication in a specific time interval (Gupta and Karisiddappa 1997), the measure has been used for decades to normalize researchers' publication numbers (publication rate), or has been normalized by it (publication speed) (Huber and Wagner-Dobler 2001; Rubio 1992; Wagner-Dobler 1995; Gupta and Karisiddappa 1997; Huber 1998; 2001; Huber 2002). Scientific productivity is also a field-dependent phenomenon giving rise to different production patterns e.g. in physics, mathematics, engineering, biology and psychology (Ortner 2010; Huber 2001). It is, therefore, necessary to take into consideration the differences in productivity patterns when conducting comparative studies or evaluating researchers. This implies that comparison of scholars, regardless of their disciplines, would lead to unreliable results.

In Gupta and Karisiddappa's (1997) study of active authors in Genetics, the distribution of scientific productivity is near to Lotka's and binominal distributions. However, distribution of publication speeds is closer to Poisson rather than Lotka's Law. Huber (1998) on the other hand shows that publication rates and scientific career durations follow exponential distribution. Later in 2001, he indicates that the model best fits the distributions of the indicators across different fields including physics, mathematics, biology and psychology (Huber 2001). Moreover, there is a significant difference between biology and physics, and between mathematics and psychology in terms of their authors' publication rates. In another study, Huber and Wagner-Dobler (2001) found that the temporal model of scientific production follows Poisson distribution. In addition, exponential distribution serves as the best fit for authors' publication rates and scientific career durations. Huber (2002) also developed a new model for a process that generates Lotka's law. The model fits different informetric distributions including publication rate, career duration, randomness, and Poisson distribution over time. One of advantages of the model is in its ability to provide insight into the causes of differences between samples.

In general, the literature highlights the research interests to find new approaches to objective scientific evaluation based on career duration measure. However, no study that focuses on disciplinary differences in scientists' scientific career durations can be located. To acquire a fairer research evaluation and avoid biased and myopic judgments, Iranian academic milieus have been elaborating regulations based on a set of indicators, including the number of publications indexed in Thomson Reuters (formerly the Institute of Scientific Information, ISI) or Islamic World Science Citation Center (ISC) databases, journal impact factor (JIF) or Source

Normalized Impact per Paper (SNIP) of the related journals, the amount of research grants previously absorbed, and hot papers. These are determinants in critical junctures of scientific lives such as in getting employed, tenured, promoted, and receiving research fundings. However, the regulations generally take into consideration neither the researchers' specialties, nor their SCDs. To the best of our knowledge, no study has explored the effect of SCD on scientific productivity level in various disciplines in the Iranian context. Hence, the question is whether researchers in different disciplines significantly differ in their SCDs, and if so, whether such differences contribute to differences in their productivity levels. To answer the question, the present study attempts to compare Iranian researchers' SCDs across various disciplines during 1991-2011 and to evaluate its impact on their scientific production. While providing a more accurate picture of Iranian researchers' productivity, the findings of the present study may highlight the importance of taking SCD into consideration in normalizing the number of publications in cross-disciplinary comparisons.

OBJECTIVE AND METHOD

The main objective of the study is to explore the impact of Scientific Career Duration (SCD) on evaluating Iranian researchers' scientific productivity across disciplines. In order to achieve the aim, it tries to answer the research questions as follows:

a) Do authors significantly differ in their Scientific Career Duration and Scientific Production values across different disciplines?
b) Do authors significantly differ in their Publication Rate values across different disciplines?

Applying a scientometric method, the present communication studies the Iranian corresponding authors who have long SCDs. To do so, it concentrates on those authors who published in Science Citation Index (SCI) journals in 1991 and continued to publish in the journals at least until 2011. The year 1991 was chosen as the temporal starting point to ensure the selection of researchers with long SCDs. Besides, it marks the beginning of a period when Iranian scientific community started to overcome the scientific decline of the previous decades (Osareh and Wilson 2005; Sotudeh 2012).

The Identification of Researchers

In order to identify the Iranian researchers for this study, we first conducted a search in SCI using the search formula: "CU=Iran AND PY=1991". The names and affiliations were extracted from Reprint Address (RP) field to check the identity of the researchers. In cases of insufficient information, we verified their identity by searching Google, using a conjunction of each author's name with a part of his/her article title, email or affiliation. This resulted in the identification of 95 researchers.

The examination of the researchers in the subsequent years (until 2011) indicated a great variety in terms of their SCDs (ranging from 3 to 21 years). Therefore, to facilitate comparison among the researchers, they were categorized into three groups: (a) Short SCD (3-7 years), (b) Medium SCD (8-14 years) and (c) Long SCD (15-21 years). The group with Long SCD had the highest frequency (81, 85 per cent) and most of them having reached 21-year and thus the longest SCD (68, 83.95 per cent of the group). This group was revealed to have the highest portion of the total scientific productions as well (Table 1).

Table 1: The Scientific Production of the Researchers in Groups with different SCDs

Scientific Career Duration (SCD)	Researchers		Papers	
	Frequency	Percentage	Frequency	Percentage
Short SCD (3 -7 years)	8	8.42%	30	0.71%
Medium SCD (8- 14 years)	6	6.31%	39	0.93%
Long SCD (15 -21 years)	81	85.26%	4137	98.36%
Total	95	100%	4206	100%

The results obtained from the Pearson correlation tests showed a significant decrease in the number of scientific papers in the Medium-SCD group (r= -0.79, Sig.= 0.006), while a significant increase in the Long-SCD group (r= 0.94, Sig.= 0.0001) over time.

The results obtained from regression analyses confirm that scientific production has been diminishing on a linear basis in the Medium-SCD group, while has been exponentially growing among the Long-SCD scholars. Based on the coefficient of the exponent (n=0.099), the annual increase does not exceed about 10 per cent annually (Figures 1 and 2).

The decline in output observed among the Medium and Short-SCD groups may be attributed to their scientific inactivity. Besides, as Jones et al. (2014) put it, it may also reflect preferences toward retirement or declines in health in later life. To clarify the reason, we examined their current situations by searching their profiles on the Internet. Out of the 14 members of the two groups, two were found retired and five were still continuing their academic tasks - as university educators, translators or authors of Persian texts. No information was found on the status of the rest. Given the incompleteness of the information, no firm conclusion can be drawn on the probable role of scientific sluggishness or retirement in the downfall. The groups were therefore excluded from the study to avoid probable effects of a rather heterogeneously active population on the findings.

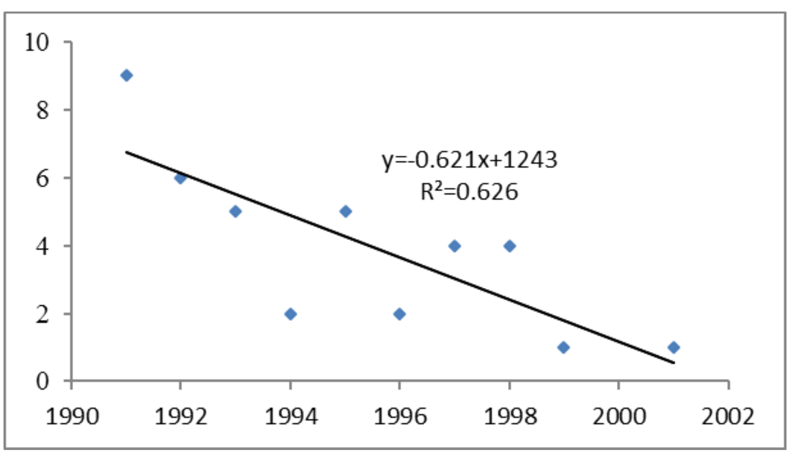

Figure 1: Regression Analysis of Publications vs. Years among Researchers with Medium SCD

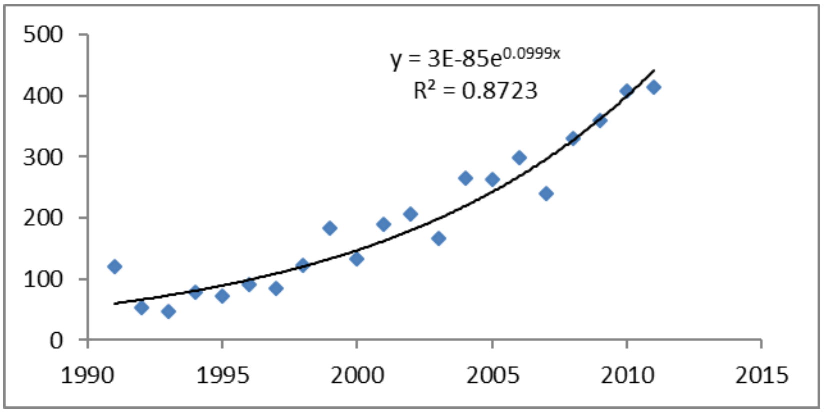

Figure 2: Regression Analysis of Publications vs. Years among Researchers with Long SCD

Subject Classification of Researchers

Two classification methods were used in order to control possible effects of a single classification method on the results. The first was based on the journals subject categories (identified in the SC field of the data downloaded). Given the high number of the categories and their narrowness, the SCs were re-classified into the more general 22 Essential Science Indicators (ESI) classes using the conversion table developed by Didehgah (2009) based on Leydesdorff and Rafols (2009). Economics & Business and Social Science were excluded from the study given their incompatibility with the scope of the research subjects.

Depending on the selected publication strategy, a researcher may publish in several journals, each classified in one or more subject classes. As a result, the publications of a single researcher may be distributed in two or more classes. The data dispersion may undermine the results due to the lack of the integrity of a researcher's data. Besides, a researcher's area of expertise does not always correspond with the subject of the journals she publishes in.

To avoid any probable effects of the flaws, the analyses were repeated at departmental level, classifying each researcher in just one department, based on their affiliations recorded in RP field (or C1 field, in cases where the former had been left blank). In cases of insufficient information, the authors' departmental affiliation were checked by searching on Google. Three researchers were eliminated from the analyses due to the lack of information regarding their respective departments. The names of the departments were verified to ensure their consistency. Finally, 36 departments were identified, of which 23 consisted of just one researcher having published in 1991. This is caused by the wide temporal range selected to take longer SCDs into account. By eliminating these researchers, the number of the departments to be studied decreased to 13. Although the classification retains the integrity of a researcher, however it too, may suffer from a number of defects, the most important being the probable lack of a high correspondence between a researcher's area of expertise and her organizational affiliation.

Data Analysis Tools and Methods

The downloaded data were parsed and prepared using Excel spreadsheet and then analyzed using Statistical Product and Service Solutions (SPSS). Inferential statistics including Pearson correlation, Regression Analysis , Welch and Brown-Forsyth tests (in case of normality, while non-homogeneity, of data distribution) as well as Kruskal-Wallis and Mann-Whitney U Tests (in cases where Kolmogorov-Smirnov Test rejected the normality of distributions) were used.

FINDINGS

The verification of the number of papers published by the researchers revealed that they largely vary in their scientific production patterns. The scientific production of the largest subgroup with the longest scientific life cycle (i.e. 21-year SCD) ranges from 2 to 270 papers signifying a high degree of skewness and, thus, a variety of scientific production patterns.

The Comparison of the Researchers' SCD and Paper Means across Departments
Given the non-normality of SCD values distribution at department level, the Kruskal-Wallis test was used to compare researchers across departments in this regard. According to the results, the SCD values revealed no significant differences across departments (X^2=11.55, P=0.482).

ANOVA was applied to compare the departments in terms of their researchers' mean papers, given the normality of the distributions confirmed by Kolmogorov-Smirnov Test. As the Levene's test rejected the homogeneity of publications variances across departments, the robust tests of Equality of Means, i.e. Welch and Brown-Forsyth tests, were used. As seen in Table 2, Chemistry is the one and only department exhibiting significantly higher number of productions compared to some other departments including Biochemistry, Electrical Engineering, Hydraulic Engineering, Mathematics, Neurosurgery, Pharmaceutical Chemistry, and Physics.

Table 2: The Departments with Significantly Different Mean Productions

Departments		Mean difference (i-j)	Standard Error	Sig.
i	J			
Chemistry	Biochemistry	93.07	20.53	0.014
	Electrical Engineering	95.07	20.05	0.009
	Hydraulic Engineering	106.73	19.32	0.003
	Mathematics	95.40	19.62	0.009
	Neurosurgery	101.40	21.15	0.009
	Pharmaceutical Chemistry	102.07	19.37	0.005
	Physics	101.07	20.50	0.008

The Comparison of the Researchers' SCD and Scientific Production across ESI Classes
Unlike the results obtained for the departments, the Kruskal-Wallis results found significant differences in SCDs between ESI classes (X^2=5.75, df=19, P=0.0001). According to Mann-Whitney U Test, applied as post hoc tests, scientists in Biology & Biochemistry, Chemistry, Engineering, Microbiology and Multidisciplinary Science have significantly longer SCD values compared to their colleagues in some other ESI classes (Table 3). For instance, the average SCD for Chemistry, the most productive discipline in the country, was significantly higher than

those yielded for Biology & Biochemistry, Computer Science, Ecology/Environment, Immunology, Materials Science, Microbiology, Molecular Biology & Genetics, Multidisciplinary Sciences, Pharmacology, Physics, Plant & Animal Sciences, and Agricultural Science.

The mean ranks of the papers were also revealed to be significantly different among ESI classes (X^2=70.22, df=19, P=0.0001). As seen in Table 3, the ESI classes with significantly higher SCD means are those exhibiting superiority in their scientific production, Microbiology and Material Science being the only exceptions.

Table 3: ESI Classes with Significantly Different Mean Ranks regarding SCDs or Papers
(*The classes showing insignificant difference either in SCD or Publications are left blank*)

ESI Classes		SCD			Publications		
Superior class	**Inferior class**	**U value**	**Z value**	**Sig.**	**U value**	**Z value**	**Sig.**
Biology & Biochemistry	Clinical Medicine	203.50	2.65	0.008	219.00	2.33	0.02
	Engineering	175.50	4.15	0.0001	211.50	3.59	0.0001
	Ecology/Environment	163.00	2.32	0.021	177.00	1.99	0.047
	Materials Science	156.00	3.08	0.002	157.50	3.03	0.002
	Mathematics	103.50	2.17	0.030	98.50	2.29	0.022
	Molecular Biology & Genetics	205.50	2.29	0.022	205.50	2.25	0.024
	Pharmacology	185.00	2.01	0.045			
	Agricultural Sciences	231.00	1.96	0.050			
	Physics				215.50	2.06	0.039
Chemistry	Clinical Medicine				326.50	2.63	0.009
	Biology & Biochemistry	146.50	4.20	0.0001	141.00	4.21	0.0001
	Computer Science	230.50	3.38	0.001	217.00	3.49	0.0001
	Engineering				468.50	2.47	0.014
	Ecology/Environment	232.50	2.77	0.006	203.50	3.18	0.001
	Immunology	93.50	2.34	0.019	68.00	2.94	0.003
	Materials Science	311.50	2.34	0.019	303.00	2.41	0.016
	Mathematics				163.50	2.10	0.035
	Microbiology	105.00	3.66	0.0001	112.00	3.43	0.001
	Molecular Biology & Genetics	265.00	3.18	0.002	269.00	3.07	0.002
	Multidisciplinary Science	117.50	4.99	0.0001	101.00	5.17	0.0001
	Neuro Science & Behavioral Science				115.50	2.61	0.009
	Pharmacology	245.50	2.77	0.006	214.50	3.19	0.001

ESI Classes		SCD			Publications		
Superior class	**Inferior class**	**U value**	**Z value**	**Sig.**	**U value**	**Z value**	**Sig.**
	Physics	263.50	3.20	0.001	244.50	3.41	0.001
	Plant & Animal Sciences	214.50	2.68	0.007	172.50	3.32	0.001
	Agricultural Sciences	277.50	3.18	0.001	207.50	4.08	0.0001
Microbiology	Materials Science	122.00	2.40	0.017			
	Clinical Medicine	148.50	2.17	0.030			
Engineering	Ecology/Environment	265.50	2.82	0.005			
	Immunology	113.50	2.15	0.032	107.00	2.27	0.023
	Materials Science	345.50	2.52	0.012			
	Microbiology	122.00	3.65	0.0001	172.00	2.71	0.007
	Molecular Biology & Genetics	308.50	3.17	0.002			
	Multidisciplinary Science	137.50	5.04	0.0001	139.00	5.00	0.0001
	Pharmacology	292.50	2.64	0.008	329.50	2.10	0.036
	Physics	308.50	3.18	0.001			
	Plant & Animal Sciences	256.00	2.54	0.011	278.00	2.17	0.030
	Agricultural Sciences	335.00	3.02	0.003	346.00	2.30	0.022
	Computer Science	270.50	3.34	0.001	319.00	3.20	0.001
Materials Science	Immunology				76.00	2.04	0.041
	Microbiology				125.00	2.30	0.021
	Agricultural Sciences				244.00	2.45	0.014
	Multidisciplinary Science				101.50	4.50	0.0001
Multidisciplinary Science	Ecology/Environment	151.50	3.00	0.003	125.00	3.59	0.0001
	Mathematics	92.50	2.91	0.004	77.50	3.33	0.001
	Microbiology				123.00	2.27	0.023
	Molecular Biology & Genetics	191.00	3.02	0.003	121.00	4.27	0.0001
	Neuro Science & Behavioral Science				96.00	2.29	0.022
	Pharmacology	159.50	2.99	0.003	140.00	3.42	0.001
	Physics	203.50	2.78	0.005	137.00	3.98	0.0001
	Plant & Animal Sciences	157.00	2.54	0.011	140.50	2.92	0.004
	Agricultural Sciences	212.00	2.77	0.006	186.50	3.26	0.001
	Computer Science	224.00	2.08	0.037	152.50	3.45	0.001

ESI Classes		SCD			Publications		
Superior class	Inferior class	U value	Z value	Sig.	U value	Z value	Sig.
	Materials Science	134.50	3.89	0.0001			
	Clinical Medicine	181.50	3.49	0.0001	162.50	3.80	0.0001

Comparison of Publication Rates of Researchers with the Longest SCD across ESI Classes and Departments

Given the scarce number of researchers with 15 to 20 SCD (T1), it is not possible to compare the publication rates of researchers in different SCD groups within a discipline. Consequently, the analyses were just limited to comparison of 21-year researchers in different disciplines. As seen in Tables 4 to 5, the analyses were carried out for a 21-year period, as well as three 7-year sub-periods in order to have closer time comparisons[1]. Given the heterogeneity of publication rates variances across departments, the robust tests of Welch and Brown-Forsyth tests, were applied to compare the departments in terms of their publication rates. The results indicated no significant differences between them in terms of publication rates of their 21-year researchers, either for the whole period or in each of the 7-year sub-periods (Table 4). Furthermore, the Kruskal-Wallis tests confirmed the equality of the researchers' mean ranks in ESI classes as well (Table 5).

Table 4: The Comparison of Departments in terms of Researchers' Publication Rates

Period	Test	F	df		P
			1	2	
1991-1997	Welch	2.138	6	7.291	0.167
	Brown-Forsythe	1.702	6	1.240	0.492
1998-2004	Welch	2.262	6	5.513	0.182
	Brown-Forsythe	4.756	6	3.184	0.106
2005-2011	Welch	3.783	6	7.116	0.051
	Brown-Forsythe	2.169	6	2.528	0.308
Total	Welch	2.138	6	7.291	0.167
	Brown-Forsythe	2.72	10	2.59	0.25

Table 5: ESI Classes Comparison in terms of Publication Rates of their 21-year-SCD Researchers

Period	X^2	Df	P
1991-1997	14.593	18	0.690
1998-2004	21.093	18	0.275
2005-2011	24.130	18	0.151
Total	27.25	18	0.074

[1] Some departments or ESI classes had not enough researchers or variances values to enter the analyses.

DISCUSSIONS

Scientometricians emphasize that the sheer number of scientific publication cannot provide a realistic picture of the scientific productivity of individual researchers, universities, institutions and countries (Huber and Wagner-Dobler 2001). Particularly, in the case of individual assessments, researchers with more or less similar SCDs should be selected for comparison (Gupta and Karisiddappa 1997). To establish the necessity and importance of taking SCD into account in research evaluations, Iranian researchers with a long SCD were studied and compared across different disciplines.

In line with Huber's (2001), the findings of the present study revealed the non-normality of distributions of SCD values and scientific papers. This implies that most Iranian authors produce publications at a very low rate, while few publish at higher rates. A 21-year SCD scientists tend to be overrepresented in the sample. They have been increasingly publishing in prestigious journals in the 21-year period. This can be promising, as it indicates that most of the Iranian scholars, who were most likely at the beginning of their scientific careers in 1991, have been scientifically flourishing in the years ahead. Surely enough, however, the pattern of their careers may not have always been at its best.

There are pros and cons to the age effect on scientific performance. According to empirical evidence provided by previous literature, academic aging is found to be directly correlated to a cognitive decline (Deary et al. 2009) and inversely associated with scientific production (Oster and Hamermesh 1998; Gonzalez-Brambila and Veloso 2007; Rauber and Ursprung 2008; van Ours 2009; Jones et al. 2014). Moreover, research time or incentives may diminish with age, owing to tenured position, engaging with more and more organizational and administrative duties, and acceptance of senior academic positions (Diem and Wolter 2011). However, the Matthew effect in science may act in favor of their research accomplishment. It brings the established academicians into a growing reputation and disproportionately more privileged compared to younger ones (Merton 1968). Specifically, multiple authorship tends to increase by age (Moed 2005), especially due to the development of the researchers' communication and collaboration networks. Furthermore, the studied researchers' career duration coincided with the period of the overall development of the Iranian scientific community (Osareh and Wilson 2002) and multiplication of the number of higher education programs and students (Mehrdad et al. 2004), paving the way towards the observed flourishing.

The research findings also showed that the researchers in various ESI classes differ significantly in their SCDs. This is in accordance with previous literature confirming the cross-field variation regarding the age-performance nexus (Jones 2010; Jones et al 2014; Simonton 1991). In fact, scientists in the fields where ideas can be identified and elaborated earlier tend to make contributions at earlier ages (Simonton 2009).

Meanwhile, the results obtained from interdepartmental comparisons showed no significant differences in this regard. The apparent contrast in the results may have roots in different classification systems, methods used in such systems and the number of categories studied. In fact, a single scholar's data might overlap with more than one subject category in the ESI classification, while the integrity of her data is retained by being classified in just one department. Furthermore, a lot of the departments failed to enter the analyses given the very limited number of their long-SCD members, whereas a majority of the ESI classes were found eligible to be studied.

The ESI classes and the departments were found to significantly differ in terms of their researchers' mean scientific papers. The ESI classes exhibiting higher SCD values consist of those outperforming in their scientific production. However, the publication rates of the 21-year-SCD researchers showed no significant differences across various disciplines. This signifies that the outstanding performance of some fields in their scientific productivity may be caused by their researchers' superiority in terms of scientific life duration. This is true even for Chemistry, the most productive discipline in the community studied (Kharabaf and Abdollahi 2012; Radmard et al. 2005). Consequently, the study of the crude number of scientific publications over a limited period of time would lead to superficial results and fail to give an accurate picture of current realities of the research realm, especially when comparing scientists from different fields.

CONCLUSION

Science destination and scientists' destinies tightly depend on research evaluation. Evaluators and bibliometricians should, therefore, keep an open eye for unintended effects of the use of bibliometric indicators. The results of the present study reveal that authors differ significantly in their SCD values and scientific production across different disciplines. However, the apparently unequal performance would disappear or decline when accounting for the SCD values. The crude publication counts, aiming to assess the quantity of the scientific productivity, can be affected by some intrusive factors, namely specialties and career durations. While young scientists are full of energy, new ideas and cognitive potentialities, their elder fellows are bestowed with cumulative advantages. This would lead to gaps in their publication rates in different phases of their lives and complicate the evaluations when comparing researchers across various disciplines. The implication of the present research is that comparison among scientists would be reasonable only if they are of the same specialties and in similar phases of their scientific lives. It is of special importance in those studies or evaluations concentrated on a single year or a limited time period.

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