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Evaluation of Moroccan research using a bibliometric-based approach: investigation of the validity of the h-index

HAMID BOUABID,[a] BEN R. MARTIN[b]

[a] *Ibn Tofaïl University, B.P 133, Kenitra 14 000, Morocco*
[b] *SPRU – Science and Technology Policy Research, University of Sussex, Brighton, BN1 9QE, UK*

This paper presents the results of an evaluation of the national research system in Morocco. The exercise focuses on the period 1997–2006 and includes a comparison with South Africa, Egypt, Nigeria, Tunisia, Algeria, Portugal and Greece. Ratings of highly ranked researchers are developed on the basis of their number of publications, number of citations and also their 'h-index' (or Hirsch index). Finally, we examine the empirical model set by Glänzel that related the h-index to the number of publications and the mean citation rate per paper for these 'upper-class' researchers. The use of this model confirms that the h-index is likely to reflect the importance and the quality of the scientific output of a given researcher.

Introduction

In Morocco, there had been very few evaluations of the research system, unlike in the USA or European countries, where evaluation is a specified task and is undertaken on a fairly regular basis. The only previous research evaluation in Morocco was carried out in 2003, and focused on the fields of natural sciences and engineering sciences [MRSM, 2003]. The work reported here attempts to provide an accurate assessment of the scientific research system using a number of bibliometric indicators which are essential to an evaluation such as this [HICKS & AL., 2004]. The evaluation measures the scientific outputs in relation to the inputs, in particular, the number of researchers, the

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Address for correspondence:
HAMID BOUABID
E-mail: h.bouabid@sussex.ac.uk, h.bouabid@hotmail.com

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number of students engaged in research studies, and the number of administrative and support staff. It aims at answering one of the question set by ARNOLD [2004]: what are the results of our actions? (e.g. impacts) in order to operate continuous improvement through observation and analysis.

A size-related indicator is used. This is constructed by first counting the number of publications produced by a given entity. We use the database of the Science Citation Index (SCI), now known as the Thomson Web of Knowledge. This indicator has been shown to provide a reasonably accurate picture of scientific production. However, the use of this indicator on its own may have certain weaknesses [MARTIN & IRVINE, 1983; KATZ & HICKS, 1998; KATZ, 2000]. These include the following: each publication does not make an equal contribution to scientific knowledge; and publication practices vary widely with speciality and institutional context. In addition, the SCI database, even though it has a wide international coverage, probably contains a larger number of relatively minor US journals than minor journals from other parts of the world; and non-English-language publications are not as comprehensively indexed. In a study conducted by QUONIAM & AL. [1995] to analyze the output of their own laboratory using three different databases (Pascal, Lisa and SciSearch), the authors concluded that the choice of the database may be more important than the choice of the indicator itself. An accurate assessment of the validity of the database must be obtained before building any bibliometric indicators from it.

Addressing the same issue, LOUISE & GOODMAN [2004] carried out a review of the Web of Knowledge (WoK) and Scopus from a librarian's point of view. The review did not conclude that one database was more relevant or better for an accurate search, but it clearly pointed out the comparative advantages of each and recommended acquiring Scopus if possible while keeping WoK. We believe that the use of the SCI is best for our purposes. Even if Pascal is assumed to be wider and to cover more non-English journals (especially French ones) than the SCI, the output for Morocco in Pascal (958 items in 2000) appears to be somewhat underestimated compared with SCI (1097 items) ([MRSM, 2003], and this study). This evaluation noted that both Pascal and ISI showed the same trends in scientific production.

The second indicator used is an impact indicator. This is based on citations – i.e. the number of references made to a publication within a given time period (the 'time window') by subsequent publications. This impact indicator is seen as reflecting the impact of a publication, rather than the quality or the importance of the research work involved [MARTIN & IRVINE, 1983]. Some problems are inherent in the use of this indicator. Among these are the variation of the citation rate during the lifetime of the publication, self citations, critical and controversial publications that may attract more attention without necessarily being of significant quality, misleading comparisons of researchers' outputs without taking into account their different ages, and incomplete coverage of all the journals referring to a publication. Also, this indicator does not necessarily take into account other valuable work by a researcher such as discoveries or research earning honours, prizes or medals. However, this partial indicator is likely to be reasonably accurate if handled with care and combined with other indicators. Indeed, NARIN [1987] reported that "*positive correlations between bibliometric measures and other measures of scientific advancements were found between:*

- citation rates to papers, and a formal peer evaluation of the papers,
- scientists' publication or citation rates, and independent measures of scientific eminence such as awards, and
- university department publications and citation rates, with peer rankings of the departments."

The third indicator used here is the recent one developed by Hirsch called the *h-index* [HIRSCH, 2005]. This index is intended to quantify an individual's overall scientific research contribution. It represents the number of papers, *h*, with a citation total for each paper that is higher than or equal to *h*. Hirsch claimed that the h-index is a reliable indicator of high accomplishment, although not necessarily for lower levels of achievement. After using his index to carry out an analysis of physicists, he argued that the h-index would be useful for other scientific disciplines.

The present evaluation is based on a ten-year time period from 1997 to 2006. A time window of five years is used [OECD, 1987] for the impact indicator – that is, the cumulative number of citations earned by a paper during its first five years (including the year of publication).

Results

Inputs

Scientific research activities in Morocco are conducted in different types of institutions: (i) those belonging to universities covering various scientific disciplines; (ii) specialized institutions that are teaching and research bodies of ministerial departments (e.g. agriculture, marine sciences, and civil engineering); and (iii) research centers that could be either multidisciplinary or specialized centers. Other new forms of institutions are emerging in Morocco called 'polydisciplinary faculties'. These are involved in a broad range of scientific activities. These institutions are not covered by our analysis (they are very few in number, as are the number of students and researchers involved).

The evaluation reported here covers those institutions engaged in basic and applied sciences, engineering and technological sciences, but it excludes social sciences, humanities and arts.

Researchers

The total number of researchers analyzed here is 7957, of whom more than 75% are in university institutions. The following Table 1 presents the breakdown according to the type of institution in which they are employed.

Table 1. Breakdown of numbers of researchers according to the type of institution

Type	Number of researchers	Percentage
University institutions	5998	75.4
Specialized institutions	1002	12.6
Research centers	957	12.0
Total	7957	100.0

The total number of researchers in this analysis represents less than half of the total number of researchers in Morocco across all research fields.

Students

The number of students is given only for the first two types of institutions. However, research centers offer largely training and research projects for students from other institutions. Table 2 shows that more than 88% of students are affiliated to university institutions.

Table 2. Breakdown of student numbers according to the type of institution

Type	Number of students	Percentage
University institutions	70,364	88.2
Specialized institutions	9,422	11.8
Total	79,786	100.0

Table 2 shows that, as for researchers, there is a dominance of students at university institutions. However, the total number of students in the fields of our evaluation is small (20.6%) compared with the total number of students (386,800).

Administrative and support staff

It is obvious that administrative staff play a key role in performing research within their respective institutions. They are mostly involved in financial, administrative, and student affairs, along with a number of social personnel. The proportion of administrative staff to researchers differs from one institution to another, but generally this proportion is higher in universities than research centers. The following table summarizes the respective data according to the type of institution.

Table 3. Breakdown of administrative and support staff according to the type of institution

Type	Administrative staff	Percentage
University institutions	3542	43.5
Specialized institutions	1779	21.8
Research centers	2823	34.7
Total	8144	100.0

We find from the previous tables that the total number of personnel involved in scientific research activities is 16 100, with almost one researcher for each member of administrative staff.

Size indicator

Table 4 shows the evolution in the number of publications for different countries during the period from 1997 to 2006. One can see that South Africa's and Egypt's outputs have been increasing steadily, with an average annual growth of 183 additional publications per year for South Africa (4.8%) and 148 for Egypt (6.6%). Despite its relatively small contribution to knowledge production in Africa (with an average of 865 publications per year only), Tunisia exhibited the highest annual rate of increase over the decade – 30% (with an average growth of 134 additional publications per year). Among this sample of African countries, Algeria also emerges as a significant and fast growing producer of science (with an average growth rate of 25.7% per year).

Morocco showed a slow but steady increase until 2001, but this was followed by a slight decline between 2001 and 2004. The average number of publications for Morocco is 1041 per year. With regards to Table 1, this means that each researcher published an average of one article every seven years in the journals scanned by the Science Citation Index. The annual rate of increase for Morocco is only 5.3% – that is, an average of 40 additional publications each year.

There could be various explanations for this comparative lagging behind of the Moroccan scientific research system. The first, of course, is language. Moroccan researchers tend to publish in French, which may adversely affect their knowledge production as reflected in SCI publications. For the sample of countries considered here, it is worth recalling that the SCI does not contain any Moroccan journals, nor any Algerian, Tunisian, Nigerian or Portuguese journals. It includes one journal from Egypt, 17 from South Africa and four from Greece, compared to 137 from France.

The second reason may be a declining interest of Moroccan researchers in publishing as they become older. The average age of researchers in the scientific disciplines analyzed here is more than 55 years. This weakness was emphasized in the evaluation undertaken in 2003.

Table 4. Size indicator (total number of publications)

Country	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Average variation/year (%)
Morocco	753	934	999	1097	1157	1121	1122	955	1157	1114	5.3
Tunisia	447	497	567	612	696	786	987	984	1424	1655	30.0
South Africa	3799	4130	4207	3970	4083	4479	4431	4404	5277	5443	4.8
Nigeria	783	777	806	872	690	761	821	810	981	1308	7.4
Egypt	2225	2359	2465	2439	2735	2757	3233	2897	3402	3554	6.6
Algeria	306	355	407	422	456	525	612	678	860	1014	25.7
Portugal	2348	2816	3409	3470	4020	4153	5344	5449	6421	7365	23.7
Greece	4385	5121	5186	5516	6440	6193	8044	7955	9735	10340	15.1

The third factor could be linked to the fact that fewer and fewer students seem to be interested in research studies leading to a higher diploma. The DESA diploma (involving five years of university studies) has been recently considered as an equivalent recognition to the previous Doctorate (or PhD equivalent) for the purposes of recruitment, particularly in the public sector. While this new rule may have provided equal opportunities for university graduates from one side and engineers from the other when it comes to offers of employment, it has, however, dramatically reduced the interest of students in research studies. Currently, only 8300 students are registered for research studies at universities against more than 10000 five years ago.

In addition, since February 1997, with a regard to a researcher's (or a professor's) career, not only are his or her research activities and publications included but also other activities such as union, cultural or social activities. The latter are given the same weight as, or perhaps even more than, research activities (Moroccan Government Decree n° 2.96.793, 19 February 1997). This situation has gradually resulted in a clear disadvantage for those researchers who are more involved in research requiring greater intellectual efforts, equipment and large amounts of uninterrupted time.

Another event occurring during 2006 that will certainly have a negative impact on scientific research output and outcomes in the near future was the government initiative to encourage earlier retirement in the public sector by giving substantial subsidies and granting the full retirement allocation. As a result, almost 36% of researchers (including those in medicine and pharmacy) have benefited from this initiative. This operation also affects the ten top-ranked authors, in particular two out of the ten most highly publishing researchers (see the section on author rankings and h-index analysis later in this article).

In the case of the Mahgreb countries considered here, namely Morocco, Tunisia and Algeria, we have analyzed their cross-cooperation as reflected in co-authored publications. We intend to assess research collaboration between these countries (which have strong similarities) compared with the total scientific output for each country. The analysis is carried out using joint publications for the whole of the period studied from 1997 to 2006. The matrix below shows the number of collaborative publications and the total number of publications for each country. The table below shows a very small cross-collaboration between these countries.

	Algeria (5635)	Tunisia (8655)
Morocco (10409)	84	103

However, strong collaboration exists between each of these countries and France for example. The number of co-authored publications between Morocco and France is 4141, which represents almost 40% of total publications of Morocco. It is likely the same situation for Tunisia and Algeria. The number of Algerian and French co-authored publications is 2602, that is 46% of Algerian publications and the number of Tunisian and French co-authored publications is 3025 which represents 35% of Tunisian total publications.

As illustrated in the Table 5, Morocco seems to have intensive and diverse international research collaborations which remain, however, dominated to a large extent by collaborations with northern countries rather than southern ones.

Table 5. Mean co-publications according to respective countries

Country	Number of co-authored publications	% of total publications produced by Morocco
France	4141	39.78%
Spain	575	5.52%
USA	507	4.87%
Italy	359	3.45%
Germany	313	3.01%
Canada	258	2.48%
Belgium	242	2.33%
UK	161	1.55%
Switzerland	103	0.99%
Tunisia	103	0.99%
Algeria	84	0.81%
Portugal	76	0.73%
Scandinavian countries	68	0.65%
South Africa	27	0.26%
Greece	23	0.22%
Egypt	22	0.21%
China	19	0.18%

Impact indicator

The analysis undertaken here is based on counting the number of citations to all the publications from a given year within a time window of the first five years (including the year of publication). Hence, the analysis comprises the time series for papers published from 1997 to 2002. We also consider the average impact, which is simply the total number of citations divided by the number of publications receiving those citations.

Table 6 shows that the impact of South African publications on worldwide knowledge production is comparatively large for the African countries considered here. However, South Africa has one of the lowest impact growth rates of 9.7 %. The average citation per article for South Africa is 5.1 (see Table 7).

Table 6. Impact indicator (total number of citations)

	1997	1998	1999	2000	2001	2002	Average	Variation /year
Morocco	2244	2825	2734	3430	3507	3753	3082.2	13.4%
Tunisia	1707	1408	1413	1820	2232	2739	1886.5	12.1%
South Africa	16415	19412	20368	20827	24078	24375	20912.5	9.7%
Nigeria	1445	1657	1698	2025	1830	3176	1971.8	24.0%
Egypt	6471	5975	6543	7871	8456	9379	7449.2	9.0%
Algeria	885	963	1360	1394	1802	1803	1367.8	20.7%

Table 7. Impact indicator (average citation per paper)

	1997	1998	1999	2000	2001	2002	Average
Morocco	3.0	3.0	2.7	3.1	3.0	3.3	3.0
Tunisia	3.8	2.8	2.5	3.0	3.2	3.5	3.1
South Africa	4.3	4.7	4.8	5.2	5.9	5.4	5.1
Nigeria	1.8	2.1	2.1	2.3	2.7	4.2	2.5
Egypt	2.9	2.5	2.7	3.2	3.1	3.4	3.0
Algeria	2.9	2.7	3.3	3.3	3.9	3.4	3.2

Over the six-year period, the average number of citations received by Moroccan publications has grown from 2244 to 3753 – that is to say, by an additional 251citations per year. Each article produced by Moroccan researchers has received an average of 3.0 citations (see Table 7). Despite its relatively low score, Morocco has shown a significant annual increase in its impact rate per year of 13.4%, which is better than that for South Africa and Tunisia.

Somewhat surprisingly, Tunisia obtained an average of 3.1 citations per paper, slightly higher than the Moroccan rate; nonetheless, the total number of publications produced by Tunisia over the last decade is just 83% of the total number of publications produced by Moroccan researchers. Once more, among the African countries considered in this analysis, Algeria had one of the highest growth rates of almost 21% annually, despite its lower number of citations. Even though Nigeria has the lowest impact with an average of 2.5 citations per paper, it has the fastest annual increase in terms of numbers of citations.

Since the average rate of citations per paper for Morocco has approximately stagnated over the six years with a value of approximately 3, it would seem that not only is its growth rate low, but also the impact of Moroccan scientific output shows little sign of improving. The scores of neighboring countries like Tunisia and Algeria (both of which use the French language widely in their research) are significantly better than the Moroccan ones.

Author ranking and h-index analysis

The ranking of researchers is carried out first on the basis of the cumulative number of publications produced during the period from 1997 to 2006; this should be long enough to give an accurate idea of the broad and sustained impact of individual researchers. Citations earned by each individual's publications are counted. Finally the h-index for each of the top ten-ranked researchers is given. The robustness of the h-index has since been confirmed by others (e.g. [BORNMANN & DANIEL, 2005; VANCLAY, 2006]), although some have cautioned about applying it to small groups or individuals [VAN RAAN, 2006]. However, the h-index cannot be used to directly compare researchers from different disciplines. Iglesias and al. suggest that in many cases the h-index should perhaps be corrected for the number of published papers [IGLESIAS & AL., IN PRESS]. In addition, Egghe has argued that the h-index fails to take account of how highly cited are the most cited of an author's papers, and that instead his proposed 'g-index' is a better indicator ([EGGHE, 2006A, 2006B]; see also [ROUSSEAU, 2006]).

The objective here is merely to determine some of the leading research contributors to science in Morocco, but without intending to make an explicit comparison between researchers. Such a comparison would require a disaggregation by specific field in order to eliminate any disadvantage that could come from comparing researchers from different fields with different publication and referencing practices. Each discipline has its own context and is assumed to follow broadly the same rules for publishing [HIRSCH, 2005].

In the process of obtaining these indicators for the top ten researchers, we have carried out manual checking and cleaning up of the respective data in order to avoid any inherent errors related to the following: name, address, field of publications, co-authors, and self citations. For example, M Hachimi from the CHU of Rabat apparently produced 74 publications (placing him 7th on the initial list), but after checking and refining the data, his number of publications falls to just 60. As a consequence, his name was taken off the list in favor of M Joual, who produced 61 publications. Another example is M. Pierrot Marcel, who is not Moroccan. For two years, he collaborated in joint research projects with partners from the faculty of sciences in Rabat, the institution to which he always referred in his articles. M Pierrot worked in the field of chemistry and his name was 8th on the initial list (with 73 publications, 161 citations and an h-index of 7), but he was not considered further in the analysis reported here of Moroccan authors.

On the other hand, there is much debate about how to deal with self-citations, which involve citations made by an individual's publication to his or her own earlier publications. Self-citations in one's own or in co-authored publications could, to some extent, bias the citation impact or the h-index, since these do not reflect the external impact of the publications on the wider knowledge base. Many of these limitations were discussed, for example in the OECD discussion of prevailing practices for the evaluation of research [OECD, 1987].

Although, in a study carried out by NARIN [1987], which considered the effect of self-citations on citation performance (in a study involving hundreds of investigators, more than a thousand papers, and many thousands of citations over the course of more than five years), the author found out that the rankings of the scientists being evaluated on the basis of their publications and citations records were largely unaffected by self-citation, even when self-citation was broadened to include not only citations from the investigator himself, but also citations from any co-authors.

Our analysis is carried out under the following assumptions:

- period of analysis: *from 1997 to 2006*, which allows for a coherent analysis and minimizes to some extent the effect of age upon the results for the various researchers being considered. This threshold is chosen to obtain a *normalized* set of results and also to be in full accordance with the previous analysis considered here.
- *shared criteria of either the author or the country*. This means that only publications for an author affiliated to a Moroccan institution are counted. It sometimes happens that certain researchers published when they were earlier affiliated to foreign institutions (e.g. for a PhD study) or when working on research projects during a short time abroad.
- the citation counts *include self-citations*.

The results are reported in Table 8. This shows for each researcher the number of publications, their percentage of the total number of publications, the number of citations, the average citations per publication, the h-index, the affiliated institution, and the field of publications. The point that emerges from Table 8 is the prevalence of chemistry and medical sciences (in particular, urology and nephrology) among the top Moroccan researchers in terms of publications. We also note that these scientists have each published an average of 6 to 9 publications per year over the last decade.

The highest average rate of citations per paper published for the authors being considered is 5, compared with the national average of 3. The highest score is earned by M. Hammouti in the field of chemistry. Table 8 also shows higher average scores for citations per paper in the field of chemistry. We also see from Table 8 that the higher the number of citations per paper, the higher the h-index.

Table 8. Number of publications, citations counts and h-index for the most highly publishing scientists in Morocco during 1997–2006

Author	Publications count	% of total publications	Citations counts	Average citation/pub.	h-index	Insitution	Discipline
BENCHEKROUN, Abdellatif	91	0.87%	106	1.16	5	CHU Avicenne, Rabat	Urology & Nephrology
HAMMOUTI, Belkhir	87	0.84%	432	4.97	12	Faculty of Sciences, Oujda	Chemistry & Materials Science
BENYOUSSEF, Abdelilah	79	0.76%	240	3.04	8	Faculty of Sciences, Rabat	Physics
HAJJAJ-HASSOUNI, Najia	79	0.76%	70	0.89	5	CHU Avicenne, Ayyachi, Sale	Rheumatology
FAIK, Mohammed	78	0.75%	97	1.24	5	CHU Avicenne, Rabat	Urology & Nephrology
BENJELLOUN, Saad	76	0.73%	76	1.00	3	CHU Ibn Rochd, Casablanca	Urology & Nephrology
ESSASSI, El Mokhtar	69	0.66%	107	1.55	5	Faculty of Sciences, Rabat	Chemistry
EL MRINI, Mohammed	68	0.65%	55	0.81	3	CHU Ibn Rochd, Casablanca	Urology & Nephrology
LAZREK, Hassan Bihi	63	0.61%	234	3.71	8	Faculty of Sciences, Marrakech	Chemistry
JOUAL, Abdennabi	61	0.59%	34	0.56	2	CHU Ibn Rochd, Casablanca	Urology & Nephrology

Using the theoretical relation suggested by GLÄNZEL [2006], we calculate the relation between the h-index (h) and the composite variable of number of publications (n) and the mean citation rate per paper (x). In fact, GLÄNZEL [2007], and then SCHUBERT & GLÄNZEL [2007] attempting to get deeper insight into the properties of the interesting h-index, has found that the latter is a linear correlation of the two fundamental bibliometric indicators as follows:

$$h = cn^{1/3}x^{2/3}$$

where c is a positive constant.

Figure 1 shows the scatter points corresponding to each of the top ten researchers in term of publications during the decade from 1997 to 2006.

The aforementioned empirical relation was applied by CSAJBÓK & AL. [2006] to a sample of 40 countries including 27 EU (UK is treated as four separate statistical entities), Crotia, Turkey, Norway, Switzerland, Australia, Canada, India, Japan, China, and USA. The c constant is found to be 0.932, with a correlation coefficient R^2 equal to 98.8% in applying the model.

Here, we test this empirical formula to the case of Morocco considering the most highly publishing scientists during 1997–2006 and by the way investigate the extent of the validity of the h-index as an easy and accurate tool to measure the quality and performance of a scientist.

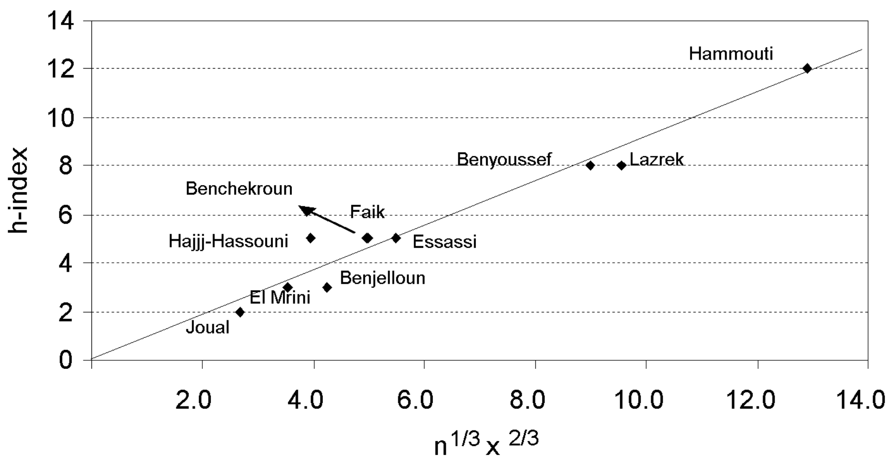

Figure 1. Plot of h-index of the top ten researchers and Glänzel's model (h=0.91$n^{1/3}x^{2/3}$; R^2=0.95)

From Figure 1 we find the correlation coefficient to be 95%. Indeed, there is a fairly close relationship between the h-index and a composite indice of other classical bibliometric indicators, namely the number of publications and the mean citation rate per paper, for a given author.

The above relationship confirms that the h-index is likely to reflect the importance and the quality of the scientific output of a researcher. This is demonstrated here for the 'upper-class' of scientists from Morocco using the empirical model of Glänzel and Schubert. Consequently, we suggest that the h-index is a reasonably reliable indicator of merit and performance.

In addition to the quantitative evaluation of the 'top ten' publishing researchers in Morocco, we have conducted a survey, in which we have questioned these ten highly-publishing researchers. The main point that emerged first from this survey is that the Moroccan researchers are apparently as competent as their counterparts around the world. This survey allows us to appreciate how high is the quality of the research carried out by the researchers in question. For example, M Benchekroun invented the deviation valve known as the 'benchekroun valve' for dealing with urinary infection, a technology that is now widely used in many hospitals. M Lazrek, who is working on biochemical approaches to therapy, has more than ten molecules registered at the National Institute of Health in USA, while M Essassi had developed certain molecules that are sold commercially by a company in Belgium.

For most of these researchers, patents are not particularly important. With the exception of M Hammouti, who has seven patents, and M Essassi who owns three patents, all the researchers believe that a scientific publication is worth more than a patent, since it means the work has been accepted by a high quality journal and the publication 'discloses' the results obtained to the whole scientific community as something that has been found for the first time by the author (or authors). Some researchers (e.g. Benchekroun and Faik) argue that they had introduced new techniques and processes that were technically difficult to patent. None of the results or techniques has yet been exploited for commercial purposes by the researchers themselves or by their respective institutions. All the ten researchers say that they use their research results all the time as inputs, tools, techniques and methods in their teaching courses and seminars, so these benefit both students and trainees.

Conclusion

During the last decade, the scientific research output of Morocco has shown little significant growth. The number of publications is still around a thousand articles per year. Over the decade, each researcher produced an average of one publication every seven years in the journals scanned by SCI. With an average rate of growth of 5.3% yearly, Morocco is rapidly losing out to other African competitors, particularly the emerging ones such as Tunisia (with a growth rate of 30%) and Algeria (25.7%). The increase in scientific impact on research community worldwide is relatively greater for Morocco than for other African competitors. Indeed, despite its relatively low score, Morocco shows a significant growth in its impact of 13.4% per year, which is better than that for South Africa (9.7%) and Tunisia (12.1%).

In the light of the rationale set out earlier in this article, we should be concerned about a decreasing trend in Moroccan scientific production in the near future. It is to be hoped that the current developments to the research infrastructure (for example, the establishment of scientific platforms, the scientific information institute, the experimental nuclear reactor, and so on), the reform of the 'poles of competencies' (networks dealing with a specific theme), the improvement of technology transfer within universities (through 'Interfaces'), and the launch of the Grand Prix for research and innovation and of the Medal of Sciences and Technology will all contribute to increasing research production in terms of size and impact. The recent establishment of the Academy Hassan II of Sciences and Technology should also contribute to strengthening it. One recommendation is to offer each researcher a financial reward for each publication he or she produces in a leading international journal. Such an incentive could also be given on the basis of an evaluation, taking into account the indicators discussed in the present article.

The quantitative indicators – size, impact and h-index – have been calculated for the ten most highly publishing researchers. This analysis, along with the results from the survey of these researchers, suggests that leading Moroccan researchers are likely to be as competent as their counterparts around the world. This qualitative survey allows us to appreciate the quality of their research, which in turn benefits their students and trainees.

Finally, we have used the model suggested by Glänzel and Schubert to measure the quality and performance of a scientist. The use of this model confirms the validity of the h-index as an easy and accurate tool that is likely to reflect the importance and the quality of the scientific output of a researcher. This is demonstrated here for the 'upper-class' of scientists from Morocco. Consequently, we support the claim that the h-index is a reasonably reliable indicator of merit and performance.

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