

2.3

DETAILED BIBLIOMETRIC ANALYSIS: METHODS AND OUTCOMES

Pier Luigi Rossi and Roland Waast

2.3.1 METHODOLOGY

In the first chapter, we mentioned the worth of ‘bibliometric’ guidelines as a means of approaching Moroccan science, referencing scientific papers signed by local authors that are published in the best world journals of their speciality. These papers are recorded on bibliographic databases, from which one can extract all that comes from a country, institution, town or author. We, then, can compare this output with that of other countries, cities, and so forth, during the same period or course of time.

There are good reasons to be interested in these publications. In theory (Merton, 1977), first of all, it is essential for researchers to seek recognition from the scientific community (‘peers’). They have to publish their results, and do it quickly (fame will be attached to originality and discovery). Even if reality is more complex than this, all perspectives recognise the importance of these publications. The competition between researchers leads to the famous ‘publish or perish’ ethos. Admittedly, science is penetrated by ‘profane’ interests and a search for resources, however, in that very quest, scientists and their allies need quality ‘certificates’, and publications in the very strictly revered journals are the more prestigious.

In practice, there is a constant and considerable increase of papers and scientific journals, which no longer makes it possible for the specialists (or the distinguished “invisible college” among them) to read them all. This was the reason behind the creation of bibliographic databases. They allow researchers to keep a bird’s-eye view on the activities in progress, get an idea of the tendencies, and distinguish the influence (quotations of others) of the recently produced works. These databases are evidently selective, reviewing a batch of chosen journals.

This is how bibliometry was born. Founded by De Solla Price, this discipline ⁽¹⁾ is based on ‘laws’ confirmed continuously by observations. The most important (Lotka law) states that the production is very concentrated; only a small part of the actors are responsible for most of the production. This applies not only to authors but also to the laboratories at

¹ Bibliometry, or better scientometry, which doesn’t use the sole bibliography databases, from now on nurtures its own journals (*Scientometrics* is the most important) its community, associations and congresses.

which they work. Surely, these actors aim at (and are sought after by) prestigious journals. As a consequence, it is legitimate to claim that science can be represented (in any case, influential science) by the content of a limited number of well-chosen journals. This is how the big bibliography databases proceed.

These databases are not immune to criticism. They have language biases, and review only very little of the 'local' journals. They reflect better the activities of basic science than those of applied sciences ⁽²⁾. They have difficulty in accounting for interdisciplinary work and are suspected to report poorly on science in the developing world (Arvanitis & Gaillard, 1992) ⁽³⁾.

Yet, regarding this last point, we can mention two original studies.

In South Africa, the first study compares a list of 'excellent' authors set by the national scientific commissions to a second list created through a 'referendum' (led by a large sample of researchers who were asked to point out their best colleagues). Both lists are compared with the PASCAL database.

One result is that the referendum ignores three-quarters of the 'excellent' researchers classified by their peers, while PASCAL knows and classifies them in good positions; this is because each researcher asked does not know other colleagues in other disciplines.

Another result is that the referendum mentions 7 times more authors than the list of 'excellent' ones selected by the peers; and PASCAL knows of 12 times more authors (that is to say three-quarters of the scientific active community, according to specialised centre, CREST). The database is thus a good guiding instrument.

The second study compares the total production reported by the agronomists from a prestigious institute in Morocco (The Agricultural and veterinary Faculty: IAV) with what several international bibliographic databases store; for instance, CAB and AGRIS, specialised in agriculture, and PASCAL, in general (Doghraj A., 1993).

From 1968 to 1990, the reported production includes 40 % papers, 30 % speeches at congresses, and 25 % research reports. Half of the papers are published in local journals. Essentially, the databases review the papers (mostly the international ones): PASCAL indexes 1 out of 5 of these, CAB 1 out of 4, and AGRIS 1 out of 3. Counting all ⁽⁴⁾, the databases miss 50–70 % of the reported production.

We have to ask ourselves if the hidden part corresponds to the preliminary outcomes (without a large analytic and practical impact) or if it is an original science (with a local view) carried out with its own methods on relevant topics that do not appear on the global agenda. This question cannot be answered. Only the experts of this domain can solve it. This is why the heart of our research system evaluation consisted of the visits made by the European peers to the laboratories.

We must know, however, that the production movement from period to period is truly accounted for by these databases (their thermometer is constant: same journals, same

² These have other expression and competition forums than just the journals.

³ Some countries create their own databases (e.g. South Africa, Japan, China, and experiments in Latin America).

⁴ The lists contain redundancies; reports and communications are handled again in order to reach the standard paper forms (40 % could have this origin). The papers are sometimes published several times (in different languages or at international level, with similar layouts).

method). Moreover, the experts agree (in all disciplines; it was the case in Morocco) that databases miss neither the excellent authors nor the main institutions.

But a number of less visible actors can be identified by experts as ‘well-positioned’ (both scientifically or socio-economically). Conversely, abundant results recorded in databases could be linked to tracks without a large perspective on a great discovery or application. Hence, when dealing with research strategies, bibliometry deserves to be completed by experts who are up-to-date with recent movements in science and technology around the world. However, bibliometry is a good tool for drawing a quick sketch, fair and sound (though not complete) of the national science: e.g. main authors, cities, institutions bearing strong points, and their evolution. It is in this spirit we built our study.

■ ***Our objective: a detailed bibliometric analysis (MICRO BIBLIOMETRICS)***

Thanks to the bibliographical databases, it is easy to follow the global performance of a country, and compare it (according to broad scientific fields) with the main producers of the planet.

But such data is neither all that matters for the science stakeholders of a developing country; nor may be the most important. Their interest is more about similar or neighbouring countries (we took African countries as a comparison). It will focus on identifying strong and weak points, opportunity niches, and sites and competent actors on which one can stand (e.g authors and institutions).

To get these details, we have to implement subtle methods that few specialists of bibliometric analysis have developed until now. We must inter alia:

- obviously choose an appropriate reference database;
- categorise each paper according to its subject code, in an ad hoc classification list ⁽⁵⁾;
- extract from the address given by the author — not only the country but also the town, institution, and even the laboratory to which he/she is affiliated.

2.3.2 PROCESSING TECHNIQUES

2.3.2.1 The choice of a reference base

Our aim was to analyse the wide variety of the basic and engineering sciences. We had to choose a general base covering all these fields. Specialised bases (e.g. medicine or chemistry) are richer but it is impossible to relate them as their methodology differs greatly.

⁵ Categories should be detailed enough to make scientific sense, and rough enough to gather a sufficient number of articles in a short period (3 to 5 years).

As a consequence, the choice was limited to the Science Citation Index (SCI), produced by the ISI from Philadelphia), or to PASCAL (a database produced by the National Institute for Scientific and Technical Information, CNRS, France).

The SCI is a rigorously built database, with a constant quality, generally used by the specialists of bibliometric analysis. Its biases are known; above all, it is in favour of English language and medicine, and not in favour of the journals of ‘small scientific countries’. By reviewing all the citations mentioned in each indexed paper, its exclusive advantage is that it allows the measure of the citations received. As a consequence, it also allows the measure of the influence of articles, authors, journals, institutions, and so forth; that is, the ‘impact’.

The production quality of PASCAL was less regular (Arvanitis et al, 2000) ⁽⁶⁾. The citations are not reviewed. But the database has the best coverage for most of the French-speaking countries, and it reviews some more local journals. Above all, PASCAL attributes to each reviewed paper one or several detailed codes describing their subject ⁽⁷⁾.

The detailed definition of strong points for Morocco is one of our main objectives, which is why we remained with the PASCAL database.

To check the results, now and then we also used SCI, and compared its macro indicators with the PASCAL ones (e.g. production volume, authors, and evolution over 15 years).

2.3.2.2 Building appropriate subfields

The codes describing the topic, which PASCAL attributes to each paper, are very detailed (too much for our needs). The ‘classification plan’, which we would eventually achieve, was a compromise between a concern for precision (detailed categories) and the constraint of statistical procedure (each ‘box’ dealt with had to contain a minimum of 5 to 10 items).

In order to satisfy this double constraint, we decided to carry out the study per subfields on the number of publications gathered through five-year periods. In that way, we could show the contributions of an institution to some rare subfields, even though they would remain invisible (statistically not significant) if they were dealt with year by year ⁽⁸⁾.

This choice allowed us to differentiate 100 subfields of research. About 30 cities and several institutions contribute to them regularly. We kept the same division made by PASCAL in regard to branches and sub-branches of disciplines. We were more detailed with some of the domains of applied sciences that were considered important by the government (i.e. agriculture and health). In some cases, we fixed boundaries so that the combination of 2 or 3 of our categories covered a multidisciplinary field of practical concern (water, for example).

The reshaping plan was a topic of debate for the ministry and the specialists. Our aim was to obtain a partition that discriminated the present capacities (e.g. avoided categories with too many or too little participants) and that accounted for the future (e.g.

⁶ The database has been evolving since 1985. For example, all authors have been reviewed since 1996 (and not only the first ones at the beginning of the reviews), and the writing notices have been standardised in a better way. The use of them in bibliometry needs, nevertheless, more fastidious work for preparing files. Inappropriate unsubscribing modified the database content around 1993–1995. The time comparison requests precaution; as a consequence, we took the 1996 year as a milestone (upper or lower bound for the periods we considered).

⁷ SCI does not do it. The papers are classified according to journal, where they are published in roughly eight great scientific domains. The shift to 100 subdomains is made by a complex and arguable procedure of attribution of subdomain ‘parts’ to each journal.

⁸ This layout also allowed the reduction of the impact of exceptional events (e.g. world congresses, and publication of an important collective book) for some years, which may have inflated the discipline or institution score.

ministry priorities, and foreseeable evolutions of the science world). It was obvious that the PASCAL subtle codes made it possible to review the division at any given moment.

We set the correlations table between our plan and the PASCAL codes. We then transcoded into our categories, the codes attributed by the database to each paper.

2.3.2.3 Sites of production

A major phase remained: to locate the sites of production (e.g. country, city, institution, and laboratory too, if necessary). For each paper, this data appears in a unique and dense field; 'the address' given by the author. We had to divide it into items, and codify each.

- The country of work usually appears at the end of the address as a three-letter code. As a consequence, we initially extracted from the whole PASCAL database the papers in which the address ends with 'MAR' (code for Morocco). This was our reference file (MAROC 1).

For better use, we transferred it to documentation software (TEXTO). We then limited the file to the items published between 1990 and 2001 (included). This was the MAROC 2 file.

Extraction of the 'cities' where the activity takes place. The next phase consisted of identifying the penultimate segment of the authors' address. As a rule, it was the city where they worked. This segment was re-positioned by us at the beginning of the address, and this new file was classified by alphabetic order of the 'cities'.

The normalisation of city names was 'handmade' from a printed listing. The authors report a large number of working 'cities'. One could observe that several of them were suburbs or districts in big cities. With a good geographical perspective of the country, we created a correlation table that linked them to their metropolis. The table carried a simple number for each metropolis, which also assisted with the problem of incorrect spelling, and was easy to deal with in the following phases.

Only a limited number of cities were codified in that way (for Morocco, there were around 20). We took into account the reported publication volume. Around 30 other cities are codified in the category 'Miscellaneous'. The other cases (e.g. towns with scores of less than 2 publications over 10 years, and addresses without city names) are not codified and are included in a category 'Others'.

When the transcription was done, we checked that the operation was satisfying (the addresses begin by a N° (number) of city). Any important 'city' had its code; what we left out were personal or rare addresses. This was the MAROC 3 file.

- Extraction of the 'institutions'. This operation was the most meticulous of all the operations performed. The institution where the author had stated he/she works had

to be identified in the 'remaining' part of the address. Nevertheless, there were several written forms for the same institution. For our bibliometric purposes, we had to choose a unique symbol to describe each of them.

The operation was done by hand, city by city on the MAROC 3 listing. This allowed us to avoid ambiguities. For example, the Centres Hospitaliers Universitaires (university hospitals), which are important actors, are often named by the authors in all cities with the simple symbol 'CHU'. To conduct a bibliometric analysis per institution, each hospital had to be assigned a particular acronym.

The identity of establishments was better detected city by city. The examination of the listing guides towards the coding strategies was most often done in an upside-down funnel manner, starting from the most specific (unquestionable 'brand' of an institution, for example the postal code) to the least specific (e.g. College of Engineers and universities, without other precision). In each city, we had to search for discriminating words (or phrases) in the lowest number possible, which would account for the whole of the observed corporate names (with their numerous written forms).

A correlation table established the one-to-one link to an institution, itself represented by an acronym. After application, the MAROC 4 file was obtained, where the references were classified by addresses beginning with a N° (number) of city, and then by a symbol of institution.

The operation was tedious. The advantage being that it was revised quickly on periodical upgrading. The experience showed, for example, that in the span of five years, there were only a small number of new productive institutions (or original written forms for corporate names). If the first coding was done well, we believed it would be strong.

- Extraction of 'laboratories'. By proceeding as in the previous phase, it was possible to identify (in MAROC 4) the laboratories inside the institutions, and to attribute an acronym to them. It was only relevant for very productive and long standing laboratories, and there were not many.

The proceedings of the data begin now.

2.3.3 OUTCOMES

The aim was not to compare with Japan or the US, and that was why we didn't calculate the 'world shares' held by each discipline. To better focus on Morocco's interior phenomena, we presented instead the number of indexed publications, which was more useful at the micro level of cities and institutions). When necessary, we used Africa as a comparison horizon (it offered enough heavyweights to compete with).

For the authors, cities and institutions, we presented ‘integer counts’ of their ‘participations’ in scientific creation, which meant that we gave one point for each paper with an address of at least one Moroccan author. Thus, in our counting, a paper co-signed by two Moroccan authors from the same institution would get one point for that institution and one point for each author. Another paper signed by two Moroccan authors belonging this time to two different institutions would get one point for each institution and one for each author.

Another way of counting the contributions (fractional counting) was to give a fraction of a point to each author of a paper in relation to the total number of authors. In the preceding cases, if two foreign authors were added to Moroccan authors, each institution and each Moroccan author would be credited with one-quarter of a point (i.e. two times one-quarter of a point for an institution accommodating two authors). The latter way of counting was ‘fairer’ but not convenient for us. The aim here was not to evaluate people or institutions but to identify the sites and the capacities. ‘Participations’ in the writing of papers were their best indicator in each precise field ⁽⁹⁾.

In some cases, we compared the PASCAL outcomes with the SCI ones. This was to check the results (evolution in time of the recorded production) or as a matter of precaution (varying the ways of catching the evolution of the most productive authors). We will see that both databases agreed to a great extent on the main tendencies.

2.3.3.1 Global view

This study was done after another one was carried out under the more general frame of research on ‘sciences in Africa’ (Waast & Gaillard, 2001). It highlighted the rapid expansion of Moroccan science between 1987 and 1996, against the general trend present on the rest of the continent. The resumption of this study with more details (e.g. precise bibliometry on the scale of the institutions and of the 100 science subfields) confirmed the tendency and specified it (1997–2001). In both cases, we took into account the Moroccan publications recorded on the PASCAL bibliographic database. Sometimes, we confronted this data with SCI data, and both sources converged on the main points.

2.3.3.1.1 The rapid expansion of Moroccan science (1987–1996)

Our first study showed (Figure 1 below) that for the period 1990–1996 there was a powerful expansion of Moroccan scientific publications (the indexed production from 1990 to 1996 doubled from 242 to 510 publications per year in PASCAL, Waast & Rossi, 2001). This rapid expansion was in sharp contrast to the general recorded movement of the African continent. While the two giants (South Africa and Egypt) struggled to maintain their scores and lost positions in the world competition arena, Morocco propelled itself to the first rank of the outsiders, more or less *ex aequo* with Tunisia.

⁹ The number of indexed papers is not equal to the number of ‘Participations’. It is inferior since the same paper could be attributed not to one but to two or more institutions (e.g. authors and cities). In the comparative tables of our cities (or institutions), we presented the number of participations, and gave (as a matter of interest) the total number of the corresponding papers in a summary column.-

At the same time, Nigeria, formerly ranked in third place (in terms of African scientific power) lost half of its contributing capacity to world science, and Kenya progressed but with a lower rhythm than other Maghreb countries. As for other African countries, where research had gone through a deep institutional and professional crisis, despite efforts by some great personalities that managed to preserve some strong points, their global scores were very modest (Arvanitis et al., 2000).

Moroccan progress from 1987 to 1996 is all the more amazing considering there was no articulated national policy to support it. In her monograph on Moroccan science, in 2001 Mina Kleiche highlights the role of strong figures who began the construction of scientific fields and institutions that developed research culture (i.e. IAV, and Rabat and Marrakech universities). She shows the constitution of intellectual circles and the deep-rooting of science in the professions (mostly medical, and sometimes engineering). She takes into account the constant and faithful cooperation maintained by Moroccan researchers with world science, with which the first links were established initially through education (PhD), and then kept going thanks to bilateral cooperation programs (with France mostly and through ups-and-downs with the US).

One also has to consider a decisive factor consisting of the regulation of the academic profession. This was in relation to the requirement to present a substantial piece of research for each change of grade ⁽¹⁰⁾.

For the following years, 1997–2001, our new study extends the analysis made with the PASCAL database. These were the years when the active and voluntary national research policy was built up. Thus, we were able to compare the outcomes of both periods, and to comment on the differential progress made.

2.3.3.1.2 The increase is confirmed (1997–2001)

The 1997–2001 data confirms an increase in relation to previous years. Following PASCAL, Morocco again doubled its production in this short period (moving from 510 to 1 010 references indexed annually).

Table 1. Evolution of Moroccan scientific production (1996–2001).

Years	1996	1997	1998	1999	2000	2001
No of papers	510	598	948	1 058	958	1 010

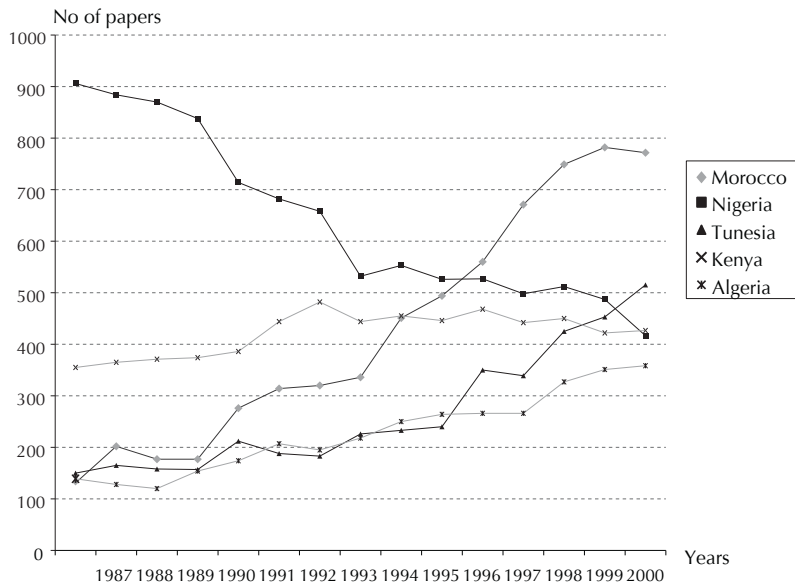
Number of papers per year, recorded in PASCAL database.

In the scientific world, such success is exceptional. Again, this evolution runs against all that could be observed in Africa in this period. The fall in rank for Nigeria as well as Kenya's difficulties, linked to a general science crisis in 'middle Africa', have not subsided (Waast, 2003). Egypt progresses slowly. Tunisia obtained a clear rebound after 1997. However, it is Morocco that shows the strongest progression in Africa during this last decade.

¹⁰ There are several 'theses' to consider (not only the PhD).

From now on, Morocco ranks third as a producer of science on the African continent (¹¹). The Science Citation Index, although uncertain in 1996, now confirms this rank beyond a doubt. The trend over a long period is depicted in the following figure. We limited it to the 'pursuing pack' of the two main producers in Africa (South Africa and Egypt, which are not shown here but are unattainable right now).

Figure 1. Evolution of scientific production (1987–2001) in five African countries: Morocco, Tunisia, Nigeria, Kenya, and Algeria



Data: SCI. Processing: PL Rossi.

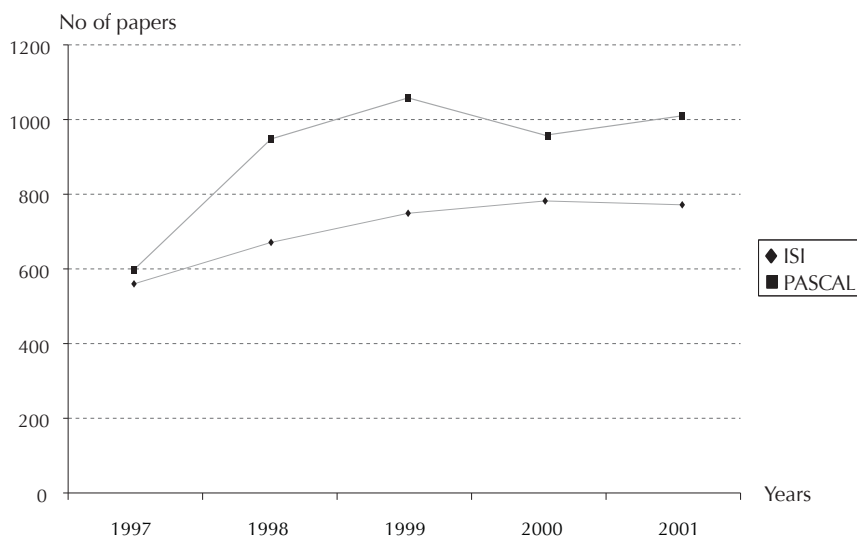
2.3.3.1.3 A plateau seems to appear (2000–2001)

During these last two years, 2000 and 2001, both PASCAL and SCI databases are in agreement when it comes to recording an inflection of Moroccan growth. This 'pause' is represented in Figure 2. The new trend conveys conflicting tendencies for both a continuing of this momentum and deep reorganisation. We shall analyse it next. We interpret this break not as a sign of exhaustion but as a consequence of several other tendencies; for example, diversification of sites, interest in new specialities, arrival of new generations, restructuring, and the need for a new professionalisation.

First, we will examine the strong points and the most successful domains of Moroccan science.

¹¹ Behind South Africa and Egypt, which are beyond reach right now. However, the three associated Maghreb countries come close to the Egyptian capacity (from now on).

Figure 2. Break of the Moroccan growth (1997-2001): comparative data of ISI (Institute for Scientific Information) and PASCAL



Data: SCI & PASCAL. Processing: P.L. Rossi.

2.3.3.2 Domains of Moroccan science: from foundations to diversification

We arrive here to a detailed bibliometry, developed especially for the evaluation of the Moroccan research system. We will investigate the specialities and the strong points of the country by examining its achievements in about 100 subfields.

This is what the PASCAL database makes possible by attributing to each reviewed paper a very detailed code (sometimes several) describing its topic.

2.3.3.2.1 From the origins: solid foundations in basic sciences (1987–1996)

In PASCAL (Waast & Rossi, 2001), we surveyed the domains where research efforts were concentrated during the studied period; those where Morocco gained a remarkable share of the African production, and those which can qualify as its strong and weak points (a ratio of the position gained in Africa to the efforts invested).

In terms of research efforts, the distribution comes close to that prevalent in the rest of the world. The basic and engineering sciences account for 50 % of the production, the medical sciences 40 %, and the agricultural sciences around 10 %. The profile differs from that of the rest of Africa (except South Africa) where agricultural and medical sciences are better represented).

Table 2. Main domains of Moroccan production (1987–1996)

% of indexed papers	Agriculture	Medical Sc.	Basic Sciences	Engineering Sc.
Morocco (1987–1996)	12 %	38 %	40 %	10 %
North Africa	9 %	29 %	42 %	20 %
Rep. of South Africa	8 %	36 %	39 %	17 %
Other Anglophone Af.	21 %	48 %	21 %	10 %
Other Francophone Af.	15 %	63 %	19 %	3 %
Africa	12 %	39 %	37 %	12 %

NB: The social sciences are excluded from the analysis.

Data: PASCAL (1987–1996). Processing: R. Arvanitis.

The basic sciences include a significant part of mathematics⁽¹²⁾. The rest is shared in more or less equal parts between physics, chemistry, geosciences and fundamental biology. The medical sciences include relatively few basic biology papers.

For the record, in this period the other countries of north Africa offer similar profiles but with nuances. Egypt shows a considerable concentration of research in chemistry as well as in engineering sciences, where it excels and holds first place ranking on the continent. Algeria's strong point is physics (and it enjoys a rather good position in several engineering sciences and to a lesser extent in chemistry). Tunisia ranks among the main African countries for mathematics, and to a lesser extent for basic sciences and clinical research.

Some interesting features appear when we analyse the subfields where Morocco distinguishes itself. Table 3 summarises the domains where efforts are concentrated, and where these efforts count for a significant part of African production⁽¹³⁾.

The major characteristic is that the effort is concentrated on the basic sciences, and more precisely on its basic subfields (e.g. botany, basic geology, general physics and chemistry, and mathematics). Outstanding successes and strong points are related to these 'fundamental' subfields (even when they are not the object of an exceptional concentration of papers, e.g. zoology, oceanography, marine biology, and all branches of mathematics).

In other domains that are less institutionalised, the situation depends more on the whims of fortune. In the medical sciences, great successes (e.g. neurology and radiology) are organised around key personalities. In the agricultural sciences, animal pathology became

¹² Four percent of all Moroccan references equates to more than we can observe in most of the world, and twice as much as in the rest of Africa (south of the Sahara).

¹³ 'Strong points' are in fact specialisation indicators; Morocco's share in African production (in a specific subfield) as compared to its share in the corresponding domain (e.g. agriculture, and medical sciences).

a notable speciality early on ⁽¹⁴⁾. In the engineering sciences, the good outcomes in materials science and metallurgy render strength in physical chemistry and crystallography. The favourable position of civil and nuclear engineering results from the dynamism of a specific institution in charge of them.

Table 3. Focus and strong points of Moroccan science (1987–1996)

Main fields	Focus	Strong points	Weak points
Agriculture & Biology (non-medical)	Animal Science Agronomy Plant science	Animal Pathology Marine Biology & Zoology	
Clinical Medicine	Internal medicine Neuropathology Radiology	Cardiology Neuropathology Radiology Nuclear medicine	Public Health Infectious Diseases
Medical biology	Microbiology Physiology		
Geo-sciences	Geology Geophysics Oceanography	Geology	
Physics	General Physics Nuclear Physics Solid State Acoustics	General Physics	
Chemistry	General Chemistry Physical Chemistry	General Chemistry Physical Chemistry Medical chemistry Pharmacy	
Mathematics	All subfields	All subfields	
Engineering	Metallurgy Materials science Electronics	Metallurgy Materials Science Nuclear Engineering Civil Engineering	Mechanical Eng. Computer Science

Data: PASCAL. Processing: Waast & Rossi (2001).

Note: focus is linked to concentration = subfields in Morocco that concentrate more than 15 % of the production in the main field to which they belong. Items have been highlighted in the table when these are a particularity in Africa.

Strong points: Moroccan share of the African production in this subfield is at least two times superior to the usual share of Morocco in all the subfields. This indicator is built up taking into account the concentration of the efforts (both Moroccan and African).

At this point in time, Moroccan science is at the same time strong and ‘incomplete’. This is neither surprising nor worrying. With limited strengths and means, it is natural that some choices have to be made. The important thing is that in the beginning a strong basic capacity is built, which will be capable of developing later into a variety of precise

¹⁴ Agronomy has a recognised value but is not higher than that of other very specialised African countries (i.e. Nigeria, Ghana and Egypt) or very powerful African countries (South Africa).

specialisations. Our 1997–2001 study makes an attempt to prove such an outcome, thanks to a very detailed coding of the subfields.

2.3.3.2.2 Growth and diversification: 1997–2001

Earlier in the report, we pointed out that scientific growth in Morocco progressed during this period. It is noteworthy to analyse the components of this growth.

■ *Growth is based on previously set strong basic competencies*

Between 1991 and 1996 and beyond, Morocco achieved a solid third ranking in Africa for mathematics, physics and basic chemistry. In general chemistry, it ranked above South Africa, and above Egypt in physics of particles; in these subfields (and in general mathematics) it ranked second in Africa.

We have shown other areas in which the difference with the two ‘big’ African countries is not considerable. For example, this is the case for earth sciences (geology) and for some engineering sciences (e.g. materials and metallurgy).

The 1997–2001 outcomes show that this foundation is strong. Mathematics is increasing its results and general physics and basic chemistry are progressing. The earth sciences remain stable, and general geology shows consistently good outcomes. In biology, progress is small; this concerns basic biology as well as its applications. Nevertheless, they are supported by strong points in the past (e.g. zoology and animal physiology, which have jumped again), with some new developments (e.g. now in the plant domain)¹⁵. The number of authors recorded is increasing strongly, more so in applied fields than in basic research.

Table 4. Number of papers’ signatures per main discipline — basic and applied sciences — Morocco (1991–1996 and 1997–2001)

Disciplines	Fundamental		Applied	
	1991–1996	1997–2001	1991–1996	1997–2001
Mathematics	88	149	21	107
Physics	350	638	104	441
Chemistry	88	159	14	85
Engineering Sc.			359	778
Biology non-med.	180	192	299	658
(of which Agric.)			259	493
Geo-Sc.	256	238	243	292
(of which Geology)	103	123	180	191
TOTAL	962	1 376	1 040	2 361

Data: PASCAL. Processing: PL Rossi.

¹⁵ The capacity in regard to molecular biology and biochemistry needs confirmation.

- *The capacities become differentiated*

From the core knowledge base, a second strong force developed during the years 1997–2001. The choice of research topics evolved. Acoustics is now applied to marine studies, algebra to epidemiology, fluid mechanics to pollution problems, and metallurgy is interested in linking with agriculture (corrosion). New specialities are developing. The communication and information technologies are progressing (in Rabat, Fez and Casablanca). In physics, subdisciplines are taking off (e.g. semi-conductors and supra-conductivity). The biotechnology capacities (mostly related to agriculture) have some important quarters (Marrakech is the main one). The domains of water, pollution and energy engineering (with a variety of disciplines involved) show a particularly notable expansion (see table below — ‘progress’ in the different subfields and main laboratories involved).

Albeit with fewer details, SCI confirms these tendencies. In a study just published (OST, 2006), through this database the French Science and Technology Observer examines the evolution of Moroccan performances in 36 subdomains. It notes a jump in the world’s share of publications (globally multiplied by 2) during the period from 1996 to 2001, especially in basic physics and mathematics (multiplied by 2.5) and to a lesser degree in chemistry (+70 %).

Above all, this growth is evident in the applied research domains:

- optics-electronics-signal (x 3);
- ecology-environment (x 2.5);
- computer science (x 2.5);
- applied physics, chemical engineering, and materials-metallurgy (x 2).

According to SCI data, Moroccan papers that have the strongest ‘impact’ in the world belong to the engineering sciences (e.g. materials sciences, plant science and agronomy, and applied physics). Next, come mathematics, geology and ecology-environment, physics and medical chemistry.

These outcomes confirm the recent differentiation of Moroccan science. Fundamental research is not abandoned. Instead, it nourishes higher education, whose quality remains undisputed. On this foundation, applied subfields are being built up with great success ⁽¹⁶⁾.

2.3.3.3 Redeployment of the production sites

The deployment of new topics is based on the restructuring of institutions and sites where the papers are produced. This is what precise bibliometry reveals.

¹⁶ The European experts who visited the laboratories underline this point.

2.3.3.3.1 Production sites become more diverse

A new element appears with the powerful growth of universities in provincial cities. Meknes and Agadir are an example, and even more so Fez, El Jadida and Kenitra. They are the cities where research production has grown most (multiplied by three or more). Next (multiplied by two or three), are Oujda and new sciences and technology faculty sites (i.e. Errachidia, Mohammadia and Settat). The cities with great scientific tradition progress in a limited way (i.e. Casablanca and Marrakech) or almost imperceptibly (Rabat).

Table 5. Number of articles (integer count) per city (1991–1996 and 1997–2001)

No of signatures	Agadir	Casa	Fez	Jadida	Kenitra	Makch	Meknes	Oujda	Rabat	Tet., Tang	Misc.	No of Articles	No of Particip.
1991–1996	76	204	95	59	61	394	90	64	836	60	61	1 530	2 002
1997–2001	225	406	347	225	232	642	278	155	954	115	158	2 972	3 737
Multipliyng Factor	3	2	3.7	3.8	3.8	1.6	3	2.4	1.1	1.9	2.6	1.9	1.9

Data: PASCAL. Processing: PL Rossi.

Table 6. Main provincial new sites and laboratories in Morocco (some subfields: 1997–2001)

Total Morocco	Subfields/Cities	Agadir	Fez	Jadida	Kenitra	Meknès	Oujda	Tet. Tang.	Misc.
121	General Math.		8	5	8	6	10***	3	12
75	Physics (instruments & theory)	6	4	5	2	1	10***	3	1
40	Optics, acoustics magnetism	17 LIM*	3	8		1	2		2
199	Crystallography	1	16***	20 PCM**	18 lpmc***	15***	4	7	7
102	Solid state (mecan & thermic properties)	13	4	2	12	20*	1	1	2
58	Semiconductors	2	23 LPS*	3		5	11**		3
19	Supraconductors	10*	1	4		3			1
202	Solid state (electro. & magnet. properties)	15 LPS**	32 lcp*	10 lmc	5	28*		1	6
80	Spectroscopy	14*	9	3	4	4	1	1	2
111	Materials Sc.	13 LTM**	9	4	13	6	5		1
74	Chemistry (theory, phases & catalysis)	9	2	12 cpc & cca**	1	8	1	2	1
43	Electrochem., Induction	10 lcp**		1	6	3		2	2

Total Morocco	Subfields/Cities	Agadir	Fez	Jadida	Kenitra	Meknès	Oujda	Tet. Tang.	Misc.
70	Physical Chem. (surface & colloids)	1	14 EST**	7	5	5	3	7	8
30	Mineral Chem.	1	9 LCM**	2		2	1		4
28	Software	1	7**			1	4	1	2
78	Automation		11 lessi**	5	1	2	5	1	1
60	Electronics		6	9	2	4	3	4	8 Erchd**
34	Telecom.		12 lessi**	1	1	5	3	1	
119	Chem. Engin.	5	11**	1	15*	10**	9	10	5
93	Metallurgy	9 LTM*	2	8	9	5	9	2	1
183	Pollution, Decontamination	6	20**	10	15**	8	1	3	8
101	Hydrology		3	3	10**	2	4	3	1
82	Soil Sc.	1	5	11**	6	6	3	2	2
86	Food Industry	2	1	5	7***	6	5		3
67	Ecology	2	14**	3	3	1	6	3	
37	Botany, Plant Physiology	4	1	1	2	2		4	1
72	Zoology, Animal Physio	1	10**	7	4	4	1	1	3
68	Geochemistry		2	5	10**	4	2	1	3
351	Geology	18***	18***	11	11	27***	24***	15	4

Data: PASCAL. Processing: PL Rossi.

Key: * site ranking first at national level, ** ranking second, and *** ranking third.

Figures in the boxes are for the number of papers in the period. Abbreviations in the boxes are acronyms of the main laboratories.

Growth in the provinces is evidenced in defined specialities, as shown in Table 6. This table has been extracted from the full table identifying the main sites and laboratories of the country. Casablanca, Marrakech and Rabat (ancient academic centres) were excluded from Table 6. Up to now, they have claimed first ranking in many subfields. Nevertheless, in a certain number of specialities, other cities are (from now on) equal to them or even better; they became sites ranked in first or second position at national level.

At the level of Rabat and Casablanca, Meknes stands out in solid state physics. Fez has specialised with success in semiconductors. Surprisingly, Fez is also leads the way in computer science, automation and telecommunications⁽¹⁷⁾. Without feigning to be at first place, Oujda appears in a good position in a variety of branches in physics and mathematics. Jadida became the second main national site for crystallography, an important subfield in which Morocco excels⁽¹⁸⁾, and one of the main sites for all kinds of sea sciences. Kenitra developed a major multidisciplinary ‘water’ centre of excellence, with contributions in all sorts of geosciences, agricultural sciences, and physics and mathematics.

¹⁷ Thanks to LESSI laboratory through the unexpected institution, Ecole de Sciences et Techniques (EST); in theory devoted to basic technological training.

¹⁸ The first site is in Rabat and Marrakech (*ex aequo*).

2.3.3.3.2 Hearths of institutional dynamic are moving

The unequal progression of the cities is explained (in part) by the fluctuating dynamism of institutions that the cities contain.

¹⁹ In Morocco (as in France and in India (see IITs), and even the US (see Caltech, M.I.T.)) some elitist institutions, often outside the university, are in charge of training selected students to become engineers or highly skilled civil servants, managers or professors. They are called *écoles* (schools or colleges), a concept difficult to translate.

²⁰ For a long time, this *école* had the mission to train the best professors for the country's high schools (a number of them became professors at universities or directors of establishments). This mission is now fading (given that there is a sufficient number of trained people), and several key figures of this *école* have left to join universities.

²¹ Marrakech, for example, did a big leap in agricultural sciences and biotechnology. This university remains one of the national major centres dealing with water and environment issues (with Kénitra), and one of the main centres of the country's agricultural sciences and natural substances chemistry. It is also the 'capital' of mathematics. Rabat maintains a high rank in this discipline. This university also shows visible progress in physics, engineering sciences, and (above all) in biology for agriculture applications. Let's not forget Casablanca, which has a good position, most notably in physics and chemistry.

■ *The withdrawal of well-established institutions*

At this level, the main surprise comes from the apparent withdrawal of some prestigious institutions (Table 7). This is the case for some 'colleges' (*écoles*) of established reputation (¹⁹).

At the Ecole Normale Supérieure de Takkadoum (Teachers training College, Rabat) the decrease affects mainly physics and the engineering sciences, while chemistry and mathematics keep constant. The Institut Agronomique et Vétérinaire Hassan II (Hassan II Agronomic and Veterinary Institute: IAV) remains the first or second national site for research related to the food industry, farming methods, plant protection, soil science and veterinary medicine. New research is developing around environment protection and medicinal plants. Nevertheless, a decline (in the number of publications and the national ranking) is becoming evident in several domains (i.e. basic biology, agronomy, and even biotechnology, of which the IAV was a pioneer).

An interpretation of these special cases remains to be dealt with. Are the mission and vocation shifts of the *écoles normales* the reasons for their change (²⁰)? Is IAV drifting towards consultancy and development research, which makes results less fit for publishing? Experts could answer these questions. For us, what we are doing here is to measure the evolution, with a database whose method and sources do not vary.

■ *The unequal progress of the universities*

At the same time, it is worth noting that those universities that have a great science tradition progress more slowly than the newer ones. Rabat remains stable in chemistry and mathematics, and declines in biology and earth sciences. Marrakech and Casablanca are decreasing in the engineering sciences.

In a number of subfields, these institutions definitely remain active centres of production and even major ones (²¹). Besides, they have already high publication scores, which cannot progress at the same quick pace as they did in the beginning.

However, we must pay attention to these changes seen for the first time. They occurred in the recent 'break' of Moroccan growth (furthermore, they concern important producers).

Table 7. Main progress during the decade, per sites and fields: comparison of the articles produced from 1991 to 1996 and from 1997 to 2001

	Math.	Phys.	Chem.	Engin.	Agric.	Water, Vet-erin.	Biol-ogy	Geo. Sc.	Clinical Med.	Med. Bio. & Chem.
école misc.	9 1	27 5	19 3	48 12	20 9	23 20	5 4	11 10		
école EMI	8 1	19 14	7 4	33 6	6 0	39 31	2 0	3 0		
école ENS	17 14	45 72	10 10	27 49	2 1	12 10	1 3	5 20		
école IAV	0 1	0	0	25 26	42 58	18 18	11 47	15 3		
Gov. Cent. INRA	0	0	0	0	41 31	4 1	3 0	0		
Gov. Cent. misc.	4 0	1 0	1 0	10 2	14 9	11 4	17 7	31 12	50 22	34 08
Gov. Cent. LPEE	0	0	0	3 1	1	8 4	2	18 10		
Offices & Hosp.	0	0	0	11 3	9 2	31 16	7 2	34 19	63 04	64 44
Recap Outside Univ.	38 17	93 91	37 17	157 99	135 110	146 104	49 63	117 74		
Recap Univ.	218									
Univ. Rabat	33 30	177 104	20 13	81 45	42 11	18 17	22 27	45 55	771 317	244 196
Univ. Casa	23 17	144 79	20 9	46 58	13 1	18 10	24 15	24 10	590 408	237 305
Univ. Marrakech	69 38	133 70	29 23	97 107	73 25	45 35	61 48	81 96		14 0
Univ. Agadir	1 4	98 27	24 8	24 10	20 8	10 3	10 9	26 7		5 0
Univ. Fez	20 2	83 27	26 5	59 7	9 6	12 15	27 8	22 25		
Univ. Jadida	7 4	75 12	22 8	34 11	24 10	14 8	17 4	18 12		
Univ. Kenitra	13 1	63 9	13 5	38 13	19 17	26 8	10 5	25 14		
Univ. Meknes	9 2	93 19	19 15	35 3	21 8	12 6	11 9	32 20		
Univ. Oujda	14 2	40 3	8 3	34 7	4 2	5 4	11 21	31 24		
Univ. Tetou-Tangr	8 9	27 7	11 7	29 7	4 2	6 0	10 9	19 6		
Univ. misc.	21 2	45 7	20 3	31 7	13 2	10 0	11 1	6		

Data: PASCAL. Processing: PL Rossi.

Key: ■ = very quick progress, ■ = quick progress, ■ = appreciable progress, and **bold** = retreat.

In each box: figure on the left = score for the period from 1997 to 2001, and figure on the right = score for the period from 1991 to 1996.

■ The new dynamics of several écoles and government institutes

In contrast, several écoles show significant dynamics. First among them is the Ecole Mohammedia des Ingénieurs (EMI Engineering School), which shows significant progress in mathematics, computer science and telecommunication, and some other engineering sciences. Others include the College for Computer Science in Rabat (ENSIAS), the College for Agricultural Engineering (Ecole Nationale d'Agriculture de Meknès), and the Ecole des Mines de Rabat (School for Mining Engineering: ENIM, where a research team

managed to mobilise an international consortium and to carry through several sheets of the geological map of the country). Finally, one of the most famous research *écoles* is by now the Mail and Telecommunication Institute (Institut National des Postes et Télécommunications (INPT)), which recently took the lead in its domain ⁽²²⁾.

We must not forget various government institutes, centres and services that have sometimes earned a good reputation in specific subfields; especially in agriculture, earth sciences and particular types of engineering. These include CNESTEN for nuclear engineering, LPEE for water and soil, and INRA, which is in charge of plant improvement (with exceptional expertise in dry areas). They are often modest producers of ‘certified’ science (i.e. published in renowned journals) but have developed strong competencies, which are recognised by applied science users and have been published in professional media outlets.

■ *The strong growth of young universities*

Nevertheless, it is obvious that the youngest universities show the strongest growth. Fez is a good example, having made a great leap forward in mathematics and in the new technologies (e.g. information, communication, and signal processing), in physical chemistry and even biotechnology. Agadir has developed important skills in the agriculture field but also strong specialities in acoustics, supra-conductivity, electrochemistry and metallurgy. Jadida and Meknès have multiplied their skills in different areas of physics. Jadida is also the new academic centre of activity for the marine sciences. Kénitra shows a genuine research strategy (multidisciplinary in regard to water issues). Oujda stands out in mathematics and semi-conductors area.

It is important to point out that the Faculties of Science and Technology (Facultés de Sciences et Techniques) in Casablanca, Tanger, Fez, Settat, Errachidia, Beni Slimane and Mohammadia, which are designed for shorter and applied training, are part of this challenge. In fact, at these faculties academics often display greater initiative and a strong will to have their work published. The same is also true for some technology institutes (*écoles supérieures de technologie*), such as the one located in Fez, which ranks among the national leaders in several subfields — notably in signal processing.

This quick listing falls short of providing fair recognition to the explosion of research and innovation that can be seen in the young universities. These universities often owe their dynamism to good governance. Their vibrant interest in research is also based on professional norms. In several places, one can meet young researchers who left the metropolis hoping for more freedom. They do not have any other ambition but to succeed in research and conform to its standards ⁽²³⁾. Even though they do not make up the bulk of the academics, they are numerous enough in each faculty to organise into ‘communities’ and promote their activities, provided the head of the institution offers them support.

To conclude, *the scientific geography of the country is much more dispersed* than it was in the past. This is true for each discipline and every field. This has encouraged imagination to foster new research topics. But, conversely, new problems are evident: critical mass in the subfields, coordination between several sites, and sharing large equipment through effective organisation.

²² According to the experts, ENSIAS remains mainly a good place for training. This *école* has some excellent researchers but does not really support them. Institut National des Postes et Télécommunications (INPT) also has a very good training program, but research there is much in favour. It contributes strongly to the international reputation of this *école*, where more than one-third of the graduates are recruited by foreign companies before they finish.

²³ Maybe they have less opportunity (or desire) than in the capital and the big metropolis for consultancy or in accessing advisory and top jobs in the important public organisations. They take more pride practicing their job with professionalism.

2.3.3.4 From the pioneer stage to the professionalisation age

When the professionalisation of science is in its beginnings, special attention should be paid to people. Scientific activity remains an individual choice, a vocation, even though later institutions begin to be established (24). As a consequence, we moved the bibliometric survey forward to a detailed analysis of the authors. The outcomes suggest that the turbulences that Moroccan research is experiencing stem in part from the reorganisation of the scientific community.

2.3.3.4.1 A generation of authors passes the torch

We know that scientific production (in Morocco, as is the case everywhere) is very concentrated. More than half of the authors located through the databases signed only one paper in four or five years, and many of them will not produce more (they will turn to another trade).

In contrast, 5 % of the authors are accountable for 15 % to 20 % of the participation in papers, whereas 15 % of the authors are accountable for 35 % to 60 %. These 'highly publishing authors' are not only the main carriers of scientific knowledge, they are also the great 'disseminators'. They pass on their knowledge to their students and disciples, who can adapt it to 'clients' or update it through international cooperation projects and competition.

These key authors play an important role. They are often charismatic personalities, and the transition to a more organised practice (performed by more people) can be delicate. These pioneers founded specialist circles. They have served as guides for young researchers. They have printed a 'brand' onto the discipline (e.g. selection of the 'interesting' issues, methods for treating them, and curiosity or otherwise for their applications). The professional norms (i.e. ethos, standards, and the competition area) often follow this 'brand'.

In Morocco today, it seems that the first generation of these keen scientists is ready to pass on their place to newer ones. We can see this by comparing a variety of lists. The first list is the one with the most productive authors between the years 1991 and 1996, identified through PASCAL. We will see whether they remain major contributors in forthcoming years (in PASCAL: 1997–2001). Another comparison was made in selecting the authors marked out as highly productive during a longer period through the SCI database, and by determining how they behave today.

It is not easy to synthesise this very personalised data. Let's first look at what could be called 'retreats' from research.

²⁴ In Morocco recently, the new Secretariat d'Etat à la Recherche (and Ministère Délégué) carried out intense legislative work to organise and promote research activity in the country.

2.3.3.4.2 Retreats from research

We identified the ‘great publishing authors’ designated by the SCI (at least 15 publications indexed by the database during 15 years). Then, we examined the evolution of their publications in five-year intervals in PASCAL (which knows too these authors). We can distinguish four profiles: constancy, production increase, ‘progressive retreat’, and ‘radical retreat’.

The progressive retreat concerns 10 authors with impressive scores (from 40 to 95 papers indexed by SCI). Their activity has been decreasing by around half every five years since 1990. We can presume that, as their time and energy was taken up by other tasks, they have withdrawn progressively and irreversibly. This withdrawal signals a normal pattern; with increase in age and career advancement, the researchers gradually move further away from direct production. Even though they remain good advisors and useful mediators, there must be replacement forces in their team (i.e. field and establishment).

Seven of these researchers belong to the Mohamed V University (Rabat), all of them in solid state physics. In this discipline, we can say that the ‘Rabat School’ is beginning a delicate transition. Two other researchers are from Marrakech, and the other is from Casablanca.

The radical retreat concerns 35 authors identified by SCI who, for the last five years, no longer appear as active in research (PASCAL data). Twenty of them are also from Rabat. This reveals both the antiquity of the research tradition in this university, and also the important withdrawal of significant personalities, which the university will have to face.

Although not signaled by the SCI database, we added seven other authors identified by the PASCAL database. They were very active between 1991 and 1996, and then disappeared between 1997 and 2001. They belong mainly to IAV and ENS Rabat: two *écoles*, as we have shown, with decreasing production numbers in many domains. Maybe this was caused by professional changes (e.g. more consultancy, new positions as managers or a change in their trade). Such a phenomenon would not be disturbing (on the contrary, it allows for a transfer of expertise) wouldn’t it systematically hit these institutions, where the replacement of researchers is not certain. It highlights all the more how important it is to find incentives in order to keep working amongst the best.

All of these retreats correspond to a deficit of capable advisors, broken down as in the following table.

Table 8. Deficit of advisors linked to the withdrawal of ‘great publishing authors’, per city (1997–2001)

	Agadir	Casa	Fez	Jadida	Kenitra	Makch	Meknes	Oujda	Rabat	Tet.Tang.	Misc.	Total
Radical withdrawal		1	3	1		8	1	2	26			42
Progressive withdrawal		1				2			7			10
Deficit advisors		2	3	1		10	1	2	33			52

Data: PASCAL. Processing: R Waast.

2.3.3.4.3 What about the replacement?

Fortunately, all the great publishing authors have not moved away yet. As proof of their research vocation, a good many persist in their activity. Thirty authors identified by SCI are in this category. They maintain their production at a high level.

Besides, it is possible to identify ‘new great starting authors’. Observed in SCI over a 15-year period, their scores are more modest than those of their predecessors. But they are in the early period of their careers. They stand out because they show regular increase in their production (observed in PASCAL in the last 5 to 10 years). We count 43 authors in this category.

These authors are almost all located in the provincial universities, and the advancement of their institutions correlate with their specialities. The outcomes are summarised in the following table.

Table 9. Geographic redistribution of capable advisors (great authors), from 1997 to 2001

	Agadir	Casa	Fez	Jadida	Kenitr	Mkch	Mkns	Oujda	Rabat	Tet.Tang.	Misc.	Total
Persisting great authors	1	5	1		2	6	1	2	12			30
New starting great authors	4	3	7	3	3	11	5	2	3	1	1	43
(among which are highly growing numbers of producers)	3	1	2	2	1	5	5	2	0			21
Total great advisors	5	8	8	3	5	17	6	4	15	1	1	73

Data: PASCAL. Processing: R. Waast.

Finally, we tried to outline the whole of this replacement phenomenon. We looked for authors whose average production was 1 publication per year during the last 5 years (PASCAL database); although they appear neither in PASCAL for the previous years (1991–1996) nor in SCI in the last 15 years. In this category, belong 175 new authors. This is the expected replacement, broken down per city, as in the following table.

Table 10. Starting authors, per city (1997–2001)

	Agadir	Casa	Fez	Jadida	Kenitra	Mkch	Meknes	Oujda	Rabat	Tet.Tang.	Misc.	Total
Starting authors	23	20	15	12	8	29	9	5	46	3	5	175

Data: PASCAL. Processing: R. Waast.

To recapitulate, we can draw on the ensuing table.

Table 11. Evolution of human resources, per city (1997–2001)

	Agadir	Casa	Fez	Jadida	Kenitr	Mkch	Mkns	Oujda	Rabat	Tet.Tang.	Misc.	Total
Withdrawals		2	3	1		10	1	2	33			52
Great advisors	5	8	8	3	5	17	6	4	15	1	1	73
Starting authors	23	20	15	12	8	29	9	5	46	3	5	175

Data: PASCAL. Processing: R. Waast.

One can infer that the generation transition will certainly be delicate in Rabat, where 'historical' advisors are withdrawing but few new great authors are showing. In contrast, the young provincial universities benefit in the way of the most promising offer of human resources (and thus have a noticeable growth potential).

Marrakech University has to be added to them because it gives rise to a great number of starting authors. This is a result of its continued support to research. It is in this way that the university can hope to solve the difficulties in passing on the torch.

In fact, some universities are more attractive than others (or favour research more). Another point to be stressed is that the small universities are fragile when the torch has to be passed on in specific fields. For the production there is based on a small number of key figures⁽²⁵⁾.

2.3.3.4.4 Autonomisation of the scientific community

The increase in numbers of regular authors shows a process of professionalisation. This implies the spread of norms and standards, by listening to great advisors, sometimes training abroad, and taking part in international programmes.

The Moroccan scientific circles far from depend on their relations with foreign colleagues. Upon reviewing of the papers' co-signatures, there appears the existence of extended intra-Moroccan networks. The publication strategies are instructive. According to the bibliographic database ISI, the authors co-publish considerably with foreigners. However, this database has a kind of myopia vis-à-vis the local media. The PASCAL database finds different results. In French-speaking journals, and especially in the Moroccan or regional journals (when they exist), the national researchers publish on their own. They publish in Arabic too (to a lesser degree but specialised media are rare). To introduce themselves to other linguistic regions, they activate their international networks: evidence of their good connections.

²⁵ Oujda and Tetouan are in this case.

The morphology of these diverse networks (national and international) has to be turned into an inventory. Bibliometrics could be helpful.

However, it must be admitted that (if there is a desire for it) there is a long way to go for the forging of national communities based on discipline. Certainly, local relations become dense, the associations in each domain are numerous, and with small subsidies they manage to organise congresses regularly on current topics, publish the proceedings, and sometimes maintain a journal. But the research work of each individual often depends on foreign financing and facilities (e.g. documentation, equipment, and information on international programmes). Personal relationships in foreign countries often take precedence over the relationships inside and between local teams. The experts who visited the laboratories insisted on the idea of staying just a subcontractor. Obviously, the researchers have to elaborate autonomous and heuristic research strategies, and the community has to show enough cohesion to promote them. But this question of relevance is beyond the limits of a bibliometric analysis.

2.3.3.5 The special case of the medical sciences

The situation in medicine differs from the one prevailing in other disciplines.

- ***The volume of publications is argued about***

SCI credits the medical sciences with 20 % of the total science production in Morocco. This database accounts for only about 20 authors with significant scores over 15 years (against 120 names for the total of all the other sciences). In contrast, over the last 5 years PASCAL records only around 140 'great publishing authors' and a considerable production (40 % of the indexed references).

This difference reflects a specificity in this domain. The Moroccan researchers in the medical sciences have several expression forums and diverse publication strategies. These can be international but they willingly focus on their own neighbourhood (i.e. Europe, the region, the country). They find possibilities to express themselves in a variety of French-speaking journals, dealing mainly with conveying clinical knowledge to the practitioners. PASCAL reviews them and SCI does not⁽²⁶⁾.

We've used both databases. Despite the difference in methods, both agree on the main points.

- ***Strong points and weak points***

The strong points, highlighted from both databases, are the same. Previously, we accounted for them using PASCAL. In the table below are the outcomes suggested by SCI (1991–1996).

The great successes focus on particular specialities, often sophisticated, and organise themselves around key figures. Some of them have very thoughtful strategies on the choice of subject. This is the feature of pioneering science that owes a lot to its founders.

²⁶ The medical circles have a marked preoccupation for recording each little item of research, and each reflection about practice. One can find everywhere (including Morocco) many scholarly societies set up per discipline. These societies organise congresses and workshops whose proceedings are published. Two journals of continuous training are published in Maghreb, which include many Moroccan papers. Other such papers are published in equivalent French journals). SCI does not review them (mainly because they are not English-speaking). PASCAL reviews a lot of them. These remarks are true, above all, for clinical research; here, researchers are also professors and heads of hospital service, and they have a special respected status. Medical biologists are less highlighted. Their papers have to be submitted in the international competition arena because they don't have media for publishing their works locally.

Table 12. Strong points in medical sciences (1991–1996)

	Clinical Med.	Neuro.	Radio.	Cardio.	Nephro.	Bio-med.	Bio Phy.	Cyto-Histo.	Pharmaco.
Morocco's share in African production (%)	2	15.9	13.5	6.6	4.5	3	10.0	6.0	4.4
Rank in Africa	10th	2th	3rd	4th	4th	8th	3rd	3rd	5th

Data: SCI. Processing: Narvaez.

It is possible to do the reverse, and wonder about the fields of 'under specialisation'. The next table shows the main outcomes.

Table 13. Fields of Moroccan under specialisation (medical sciences, 1991–1996)

	Clinical Med.	Infectious Diseases	Haemato.	Surgery	Internal Med.	Immuno.	Public Health	Bio-med.	Parasito.
Morocco's share in African production (%)	2	0.2	0.3	0.3	0.5	1.6	0.6	3	2.6
Rank in Africa	10th	14th	14th	12th	13th	15th	15th	8th	9th

Data: SCI. Processing: Narvaez.

In comparing with the rest of Africa, we can understand that relatively less research deals with non-prevailing diseases (e.g. tropical medicine and parasitology). However, we can be surprised by the 'deficit' in publications on the topic of public health.

Haematology (more developed in the rest of North Africa) shows poorly. We notice that commonplace areas of specialisation do not necessarily produce most of the papers: surgery and internal medicine pay little attention to research.

■ *The evolutions*

Using the PASCAL database, we analysed the evolution of the production between the start (1991–1996) and the end (1997–2001) of the decade. The main results are detailed below.

- The growth in volume is significant; PASCAL records a 60 % increase of papers during the period.
- Production is still concentrated in Rabat and Casablanca (90 %). Regarding research, the young faculties at Fez and Marrakech have not yet grown significantly.

- Universities (including faculties and university hospitals) produce the bulk of research (75 % of the total). Its score increases by 40 % in Casablanca and 80 % in Rabat.
- The specialised institutes either stay fair (e.g. Pasteur in Casablanca) or progress (e.g. Institut National d'Hygiène (National Institute of Hygiene in Rabat)) in strategic domains but keeping modest scores (i.e. 10 % for medical biology, 5 % for public health, 2 % for clinical research). The military hospitals are active, mainly in some specialities (e.g. infectious diseases, trauma units, neurology, ophthalmology and pharmacology).
- Finally, we can see an increase in the research performed by health centres (as well as associations and foundations) that develop creative niches (e.g. sexually transmitted diseases, nutrition, occupational medicine, and public health).
- Quality fields have been confirmed. Cardiology and neuropathology show a strong dynamism (score multiplied by two). Pharmacochimistry appears as a new speciality (it multiplied its publications by four). According to SCI, the impact of biomedicine work doubled between 1996 and 2001 ⁽²⁷⁾.
- Passing of the torch to a new generation is not yet on the agenda.

We applied our methodology to the medical sciences, comparing author lists from period to period. The result is as follows.

Table 14. Balance of human resources per medical speciality (1997–2001)

Morocco	Surg.	Gyneco.	Pediat.	Cardio.	Neuro.	OphtORL	HGE	Uro.	Endo+	Lab.	Misc.	Total
Great withdrawals	4	1	3	4	1	1	4	1	4	1	15	39
Great persisting	12	2	1	4	2	6	4	4		6	1	42
Great starting	17	15	8	3	3	12	16	9	7	6	1	+97
Balance Great advisors	+13	+14	+5	-1	+2	+11	+12	+8	+3	+5	-14	+58
New starting authors	19	25	13	11	13	15	9	7	7	18	13	150

Data: SCI & PASCAL. Processing: R. Waast.

Key: Surg. = surgery and anaesthesia; HGE = hepato-gastro-enterology; Endo+ = endocrinology, metabolic diseases, haematology, and oncology; Lab. = laboratory, medical biology, pharmacology-toxicology, and medical imaging; and Misc. = other clinical specialities.

On the whole, the arrival of new authors (that include a significant number of highly publishing ones) makes withdrawals from research easier to deal with. The strong domains ensure a replacement, and some new specialities are steadily following this pattern (e.g. gastrology, uro-nephrology, ophthalmology, surgery, gynaecology, and to a lesser degree

²⁷ When compared with mathematics or physics, the world impact stays modest. However, it is strong for some subdisciplines (neurosciences).

paediatrics). The situation is a little tricky in some cases, such as when the production is weak and jeopardised by the withdrawal of important authors without brilliant successors (e.g. psychiatry, rheumatology, pneumology).

A review per city shows that each one preserves its own strong points. Nevertheless, Rabat shows a great dynamism in all disciplines. Casablanca shows a positive balance in gynaecology, ophthalmology, medical biology and surgery. In contrast, the transition seems more difficult in cardiology and hepato-gastroenterology (both strong points) as well as in haematology and endocrinology.

On the whole, the renewal of researchers is widely ensured, and the capacity for highly producing authors is expanding. Among authors with more modest scores, the potential remains amazingly constant. The following table accounts for this.

Table 15. Active scientific community in medical research (evolution from 1991 to 2001)

No of publications	5 to 7 articles	3 or 4 articles	2 articles	Recap. more than 1 article	1 article
MOROCCO 1997–2001	170	302	476	948	NA
MOROCCO 1991–1996	165	279	431	875	NA

Data: SCI. and PASCAL. Processing: R. Waast.

2.3.4 CONCLUSION

Fifteen years of rapid and spontaneous growth in Morocco has created a base for important scientific potential. Five years of government support has ensured it recognition and given it a starting point for better organisation. Today, Moroccan science is both vibrant and at a crossroad.

Abilities are now differentiated and have been reallocated through more institutions and cities. This means the existence of issues related to critical mass, the sharing of equipment, and coordination. A pioneering generation is preparing to pass on the torch. This has created concern about the possible incentives, motivation and type of professional model available for researchers to come.

Quality fields must definitely be cultivated. Morocco already excels in some specialities. Others remain fragile, depending on rare talents and founding figures. These talents must be detected, and support made available to the 'living treasures'.

The foundations, however, are set. Capacity in basic science is solid. From this skills and knowledge core, it is possible to develop (and identify with the help of experts, if necessary) niches that present a useful link between research and the development of the country.