Country Report

Scientific Production in Arab Countries: A Bibliometric Perspective

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There is a need for data about Arab research systems. Some recent international reports have called into question their lack of interest in developing scientific creations. Yet rapid changes are taking place. This article shows the trends and local shades of the scientific output (in terms of internationally recognised publications) in West Asia and North Africa.

Keywords: Scientometrics, Arab countries, Specialisation, Critical masses, Scientific networks

Introduction

Scientific activity in the Arab region is not well documented (for a global view, see ESCWA 1999 and 2003; Nour 2005; UNDP 2002). Compared to the metropolis of research (US, Japan and Europe) these are of course 'small' scientific countries. However, this does not mean that they have no capabilities in fields important for them. It implies rather that they

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have to choose relevant niches (anticipating opportunities and needs) (Kleiche and Waast 2008). With powerful means and the will to move into a post-oil era (or post-natural resources) these countries may soar. They will have to develop appropriate research and they must know their potential.

An assessment of their international publications is a rough estimate for this. It relies on large bibliographic databases that go through a wide core of journals specialising in all disciplines. Theoretical reasons (confirmed by experience) suggest that (at least for basic sciences and except human and social ones) they encompass a sound representation of the advancement of science[1] (Braun et al. 1985; Courtial 1990; Godin 2004; Pritchard 1969). They record its areas, contents and contributors (the last ones being identified by their names and affiliation: country, institution). When consulted on long periods, they allow bringing out *trends* and *comparing* the output of different countries. When searched in detail, they disclose information on the favourite topics, the localisation of capacities (by institution and town) and the collaboration networks backing production.

This article deals with thirteen Arab countries: three of them (Morocco, Algeria and Tunisia) are together called 'Maghreb'; three others are together called 'Machreq' (Lebanon, Jordan and Syria); five of them constitute the 'Gulf' region (Bahrain, Kuwait, Oman, Qatar and United Arab Emirates); they were joined in 1981 by a sixth one—Saudi Arabia—to form the 'Gulf Cooperation Council'. Egypt is considered on its own.

The data is from the two best-known generalist databases for non-human and social sciences: the Science Citation Index and the PASCAL database.[2] We considered them over a long period (1987–2006). We launched upon cleaning their records, breaking them down by country, institution and date, allocating to them new codes to describe the research area and the time of issue (by four-year periods). For each of the countries, we analysed the global output, its evolution by periods and main branches (eight 'disciplines'), specialisations by fields (100 'areas') and their 'impact' in the global scientific community. With a view to help policy making, we then mapped the capacities at town and institutions levels ('national scoreboards'), we searched the critical masses established within the main research centres ('atlas of capabilities'), we brought out the leading authors and drew the graphs of their scientific collaborations. Some of the noteworthy results are discussed.

Global Output: Production is Modest but Rapidly Growing

As compared to the scores of other ‘intermediary countries’ (we chose Chile, Thailand, South Africa and Iran), those of the ‘Arab countries’ are modest (500 to 1,000 articles per year—except for Egypt which had nearly 3,000). Yet they take on seats of honour in their environment. Egypt is second on its continent (after South Africa), just followed by the three Maghreb countries (Tunisia first, then Morocco and Algeria). In the Near East, Iran alone does better than Egypt. The little populated countries of Machreq and the Gulf make quick progress. Each of these two sub-regions is now equivalent to one of the Maghreb countries.

Table 1 gives a list of abbreviations of the countries according to their bibliographical code and Table 2 gives the number of publications in 2007 in the Arab countries and in some ‘control’ countries.

TABLE 1
List of Abbreviations (Country Names)

MA stands for Morocco	JD stands for Jordan	BH stands for Bahrain	EG stands for Egypt	THL stands for Thailand
DZ stands for Algeria	LB stands for Lebanon	KW stands for Kuwait	SAU stands for Saudi Arabia	Iran and Chile: full spelling
TU stands for Tunisia	SY stands for Syria	OM stands for Oman		ZAF stands for Republic of South Africa
		QT stands for Qatar		
		UAE stands for United Arab Emirates		
Together called ‘Maghreb’	Together called ‘Machreq’	Together called ‘Gulf’		Context countries

Source: The abbreviations are a convention WE established for this article, drawing from the most common country codes used by widespread bibliographical databases (Thomson-ISI, PASCAL, CAB).

TABLE 2
Number of Publications in 2007—Arab Countries and Some ‘Control’ Countries

MA	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*Gulf*	*SAU*	*Iran*	*Chile*	*THL*	*ZAF*
803	814	1304	2901	518	506	147	1213	1010	6158	3099	3075	4373

Source: SCI non-extended.

There is still an important gap with developing countries that banked for long on education and then science and now on innovation (Singapore, South Korea, or even Argentina and Chile). But one should remember that in the 1980s these were small science producers.[3] And it should be stressed that enrolment in education has been growing at a remarkable rate, even in tertiary education and for women in all Arab countries (Table 3). The future is an open-ended game, and much depends on the development strategies, S&T policies and public support to science (Table 4 gives the share of world scientific production).

As a proportion to the world production of science, the whole region counts for a little more than 1 per cent. But attention should be particularly paid to its dynamism.

A remarkable dynamism: The salient feature is unquestionably the noteworthy growth of production in North Africa. Within six years (2001–06) scores multiplied by 1.5 (by two in Tunisia and two in Algeria). During the same period they increased 1.3 times in Machreq and in the Gulf countries (with some discrepancies—the multiplier is 1.8 in Qatar, Bahrain and the Emirates; and one elsewhere). Kuwait and the Saudi Arabia stayed unchanged (Table 5).

Table 3
Enrolment in Tertiary Education

	MA	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*Bhr*	*KW*	*UAE*	*OM*	*Iran*	*Chile*	*Thaïland*
Enrolment 3ry Edu (% of age group)	13	20	26	29	35	48	Na	34	22	22	13	24	43	41
Women (% of total enrolment)	46	51	55	46	51	52	Na	63	71	61	56	51	48	54

Sources: UNESCO, UNDP: Human Development report 2007–08.

Table 4
Share of the World Scientific Production (Per Thousand)

In %	*MA*	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*Gulf*	*SAU*	*All ARAB*	*Iran*	*Chile*	*THL*	*ZAF*
Share (2000)	1.3	0.55	0.9	3.23	0.62	0.41	0.15	1.3	1.13	9.6	1.9	2.6	1.66	4.84
Share (2007)	1	0.95	1.5	3.5	0.7	0.65	0.2	1.4	1.2	11.1	5.95	4.0	3.5	5.4

Source: SCI non-extended; processing: IRD for ESTIME.

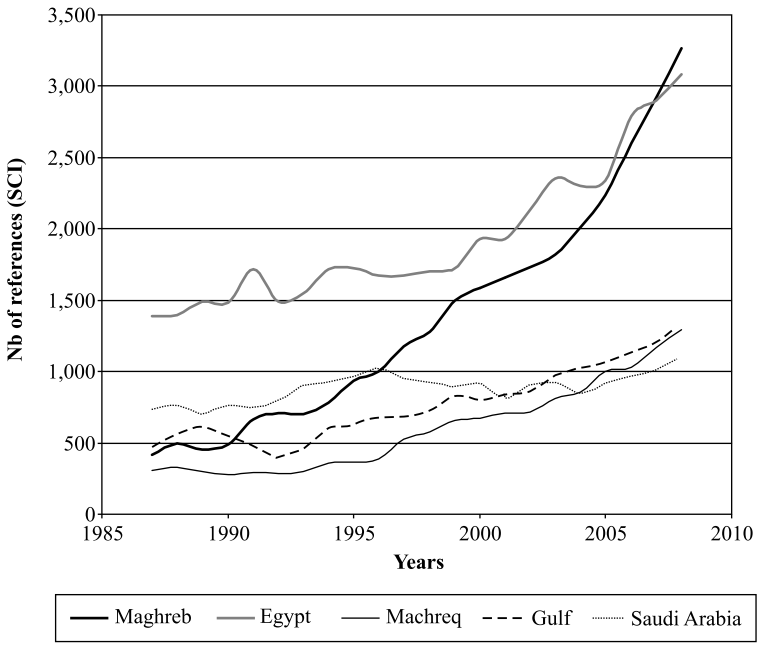
Table 5
Growth Rate of Publications, 2001–06

	MA	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*BH*	*KW*	*UAE*	*OM*	*QT*	*SAU*	*Iran*	*Chile*	*THL*
Multiplier	1.0	2.0	2.2	1.4	1.3	1.5	1.5	1.8	1.0	1.7	1.6	1.8	1.0	3.2	1.4	2.0

Source: SCI non-extended.

The most important thing is to consider the evolution over a long period. This is a way of assessing whether a research culture is rooting and which opportunities it may offer to the development of a country. Figure 1 shows how the scientific activity gained tremendous momentum during the last twenty years, especially in Maghreb.

Figure 1
Growth of Publications (Arab Countries, 1987–2008)



Source: SCI non-extended.

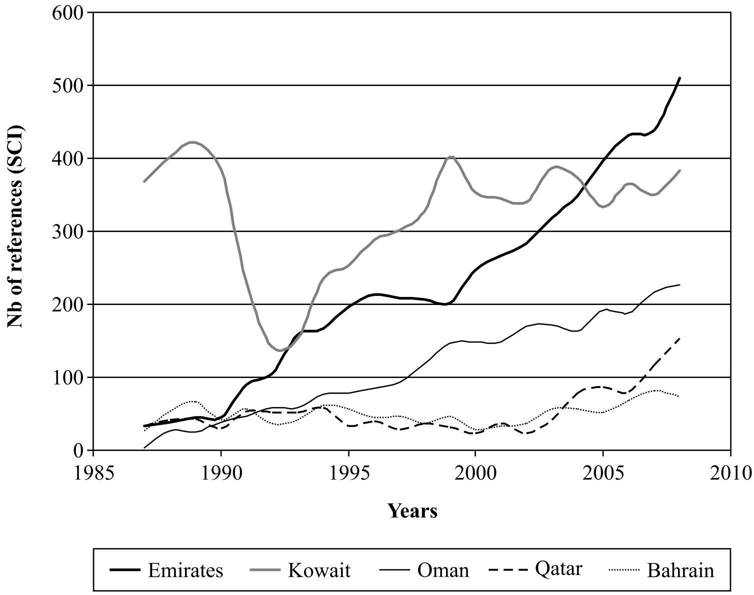
The progress of the whole region is above the world's progress. Scores more than doubled in the last two decades. Clearly this is due first to the blossoming of research in Maghreb (scores multiplied there six times). After a lasting stagnation Egypt is starting again (but not Saudi Arabia). The Machreq countries have been hampered for long by civil or regional wars. The timid growth in the Gulf hides contrasting trends: not earlier than four to seven years ago some of their governments (Bahrain, Qatar and Emirates) considered banking on innovation to face a post-oil era. They have changed their standpoint toward science and technology, which will now grow at a quick pace. This is not yet so in other places (Kuwait).

Results are sensitive to political uncertainties: This is all the more so as scientific communities are small. The advance (or retreat) mirrors political turmoil, vagaries of state support and the turnabout of development policies. As an example, Algerian production stayed on hold during the years of the civil war (from 1991 till 1998). Amazingly it did not collapse, thanks to already rooted (small) scientific communities in chemistry, physics and mathematics, some 'research' establishments and firm help from international cooperation. In Lebanon, production came to nothing with the civil war of the 1980s (1975–90), many academics flew and there was no recovering up to 1995. Jordan's output was hit by the first Gulf War (1990–91), and that of Kuwait dramatically fell down, all the more as the government expelled numerous highly skilled citizens of 'unfriendly' countries, including many Palestinians who were active in research and in higher education. Return to the 1990 level is hardly complete and there are no new advances in sight.

Development strategies and S&T policy are also influential. After a period of potent support from the state (1998–2004) research seems to have lost priority in Morocco and its results are affected. Algeria followed the opposite trajectory, and the production is growing in a spectacular way since 2003. Some Gulf states are suddenly preparing for a post-oil era, and their scientific output is leaping forward (Figure 2: Oman, Emirates and now Qatar).

The lesson is that in order to acquire sustainability the scientific activity needs to become relatively autonomous and fall within the framework of (even imperfect) scientific communities. Though the Egyptian Government did not show much consideration for the profession, a long academic tradition and the habit to publish allowed strong scientific points to stay fair. In spite of harsh life and work conditions (which fuelled structural migrations to the Gulf), the output has been preserved (1990–2000) and is rising

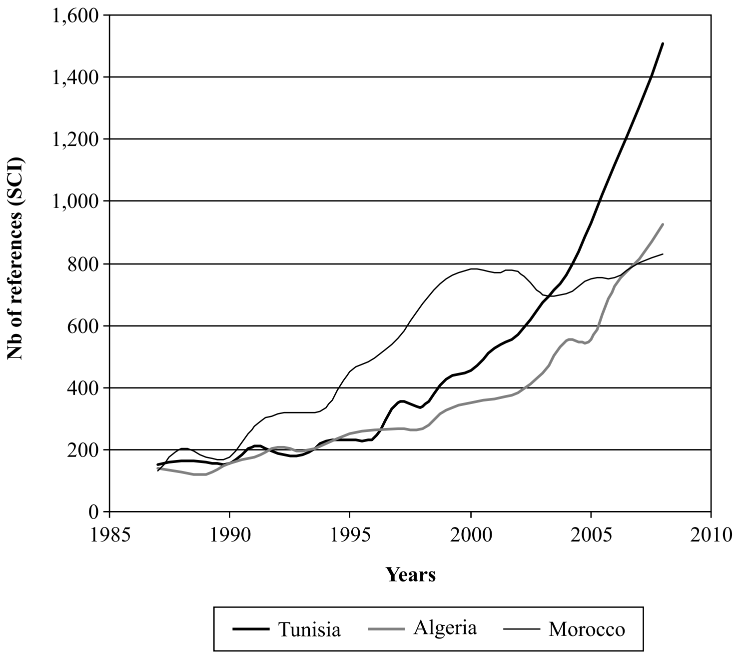
FIGURE 2
Scientific Production (Gulf Countries, 1987–2008)



Source: SCI non-extended.

again. In the same way, research is now highly institutionalised in Maghreb (statute, academic requirements and anchorage points at the university and in high civil service). It is professionalised and the researchers are impregnated with academic values, attached to their activity, and well integrated in the European (and international) community. Production no longer relies on key figures only, but on circles of specialists and sometimes on firmly established laboratories (Tunisia). Despite a strong brain drain, the local community manages to create its replenishment. A space for science has been set up and the phoenix is able to rise continuously from ashes. This makes a difference with Machreq and the Gulf[4] (where the effects of wars were disastrous and very long to make up for) to say nothing of Africa, south of the Sahara, where the withdrawal of the state support subordinated research to an international market of scientific labour, often steering the agenda. Yet these assets are fragile. They remain sensitive to the ups and downs of the social support, especially that of the governments. Figure 3 illustrates this weakness.

FIGURE 3
Growth of Production: Maghreb Countries, 1987–2008



Source: SCI non-extended.

In Morocco, the increase in publications during the 1990s was due to an academic dynamism. It was vigorously backed by the government from 1998 until 2003 when this support faded. In Algeria, during the 1990s, with civil war raging and a total lack of interest from the state academics succeeded in maintaining a small growth of production. From 2000, and even more from 2004, there was a total reversal of the situation; with peace reappearing and sizeable budgets the results were clearly affected. Tunisia is the only country in Maghreb (and in the whole Arab region) that banked vigorously and continuously on research and organised the sector for its own sake (inter-institutional laboratories and research units, with sanctuarised budgets and relative autonomy provided they are favourably assessed by international ad hoc commissions). The steady growth is striking.

A Distinctive Specialisation

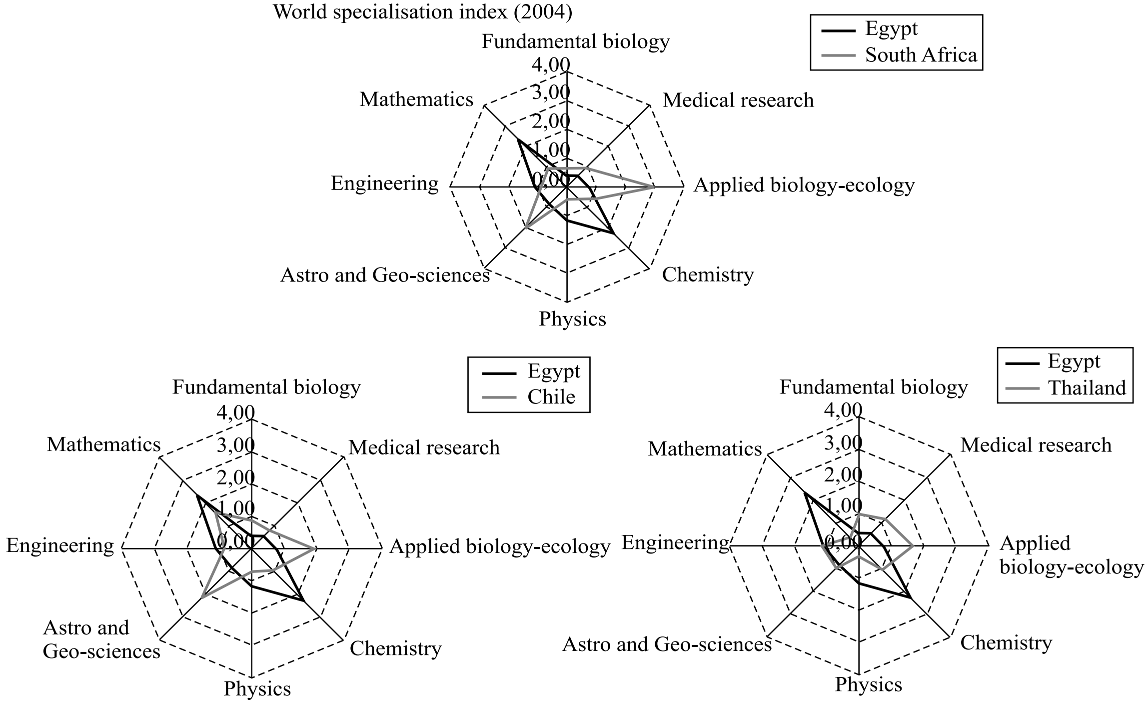
Arab countries display a very distinctive specialisation. Their publication profile is focused on exact and material sciences (mathematics, physics, chemistry and engineering). They have less interest in natural sciences (flora, fauna, agriculture and earth) and a clear under- specialisation in life sciences. This is the contrary to the rest of the world (except China), especially of most intermediary countries (Figure 4).

Figure 4 compares Egyptian production with that of three control countries. The last ones have marked peaks (representing an over-specialisation as compared with the rest of the world) concerning applied biology (namely agriculture, which is a normal feature in the developing world, and sometimes ecology, which is less usual). They have oversized capabilities in geosciences (mainly earth sciences in South Africa, and astrophysics too in Chile for this country shelters a very large international observatory). They give the same proportional attention to other disciplines than the rest of the world (except for a slight deficit in physics). Egypt has the reverse profile. Its two major peaks stand out in mathematics and chemistry, while earth sciences are less developed than in the control countries and there is a deficit in biology (very deep in fundamental biology).[5]

Of course, there are variants among Arab countries, and between the sub-regions. Through the whole of North Africa there is a marked predominance of mathematics and material sciences (physics, chemistry and engineering). Algeria is paroxysmal (even more than Egypt), with its biological sciences (applied or fundamental) and even its earth sciences reduced to the meanest share. Morocco has a more normal profile and Tunisia conforms roughly to the world's outline. Yet, all Maghreb countries can be distinguished by their exceptional interest in mathematics. The Machreq countries make more room for natural sciences, especially for applied biology (Jordan and Syria) and sometimes for medical research (Lebanon).

Moreover, each country excels in very specific sub-fields. These strong points may be due to chance: to the impulse of a key figure who trains good specialists and acquires a following; to the coalescence of researchers newly trained in a foreign country; and to the impetus given by a long-standing cooperation programme.[6] It is all the more so as the circle of scientists is small, with few critical masses and loose scientific communities. Charismatic teachers and dedicated researchers may then acquire

FIGURE 4
Specialisation Index for Egypt and Context Countries in Eight Disciplines (2004)



Thompson Scientific data, OST computing.

Source: SCI (2004); OST for ESTIME.

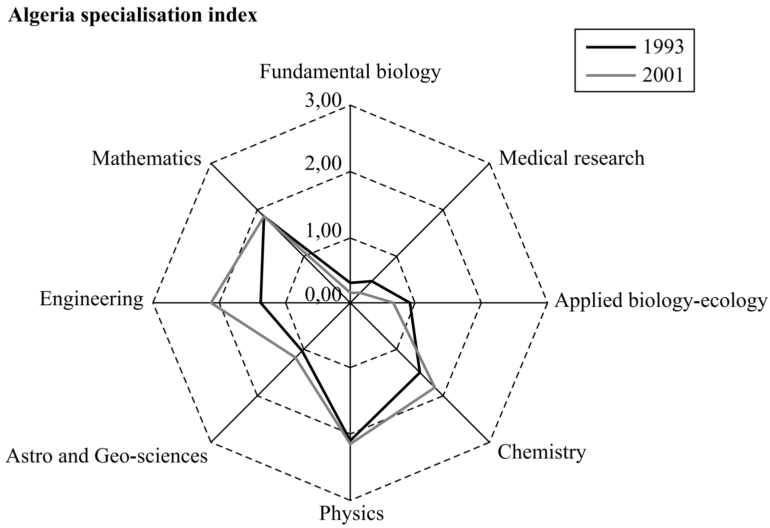
much ascendancy and leave their mark on the style of science and sub-fields in vogue. Their choices may be at odds with top-down planning; nonetheless, they are the precious ones who boost the activity, maintain it and build its stocky frame. This is why we undertook to identify them with their collaborating networks.

Yet in these sub-fields the topics dealt with are clearly oriented by a national view: they take advantage of the local material (or situation) with a frequent view to pragmatic applications. Such original capacities are an asset for the country. We tried to identify the most salient ones. The Maghreb countries may rely on solid capabilities in all sections of fundamental (material) sciences—all sorts of mathematics, general physics and chemistry. This is useful to diversify the topics to tackle, when necessary. There is not such a basic culture in Machreq. Engineering is more uneven. Algeria achieves a breakthrough in computer science, signal processing and opto electronics. Pharmacology is the privilege of three countries: Egypt, Jordan and Morocco. Algeria and also Egypt and Jordan (though without much oil resources) have strong points in energetic engineering and polymer technology. Lebanon has poor records in earth sciences, except for hydrology. Some weaknesses (not easy to understand) may also appear. Chemical engineering is comparatively little developed in Morocco (as well as computer science and signal processing). There is almost no interest in the chemistry of natural substances in Algeria, contrary to its neighbours. Computers science is not very active in Egypt (Appendix 1).

As for life sciences (which are not in favour), Egypt and Maghreb are the least specialised. But they may have some strong sub-fields. This is the case for Morocco in neurosciences or gastroenterology and for Egypt in nutrition and food industry. Tunisia is good in several branches of agricultural sciences, animal husbandry and internal medicine. Machreq countries have a balanced profile. Jordan and Syria have many strong points in agriculture and Lebanon in some medical specialities. What is somehow disturbing is that one cannot make out a specialisation in basic life sciences (like general biology, biochemistry, immunology or cellular and molecular biology).

As time elapses, old specialisations become more marked: Instead of lining up the intensity of activities with the world profile, the passing of time reinforces existing specialities. More de-specialisation occurs in under-specialised areas like fundamental biology and clinical medicine in Algeria or basic biology in Morocco and physics in Jordan. On the contrary, the activity grows even more in disciplines of high specialisation (like mathematics in North Africa, physics and engineering in Algeria, or geo-sciences in Jordan). Figure 5 shows an example (Algeria); similar ones display the same tendency in all countries.

Figure 5
Specialisation Index for Algeria in Eight Disciplines: Evolution 1993–2001



ISI data, OST treatments

Source: Thomson scientific data, OST computing.

Impact and Specialisation

The number of publications and intense specialisation do not guarantee that the topics dealt with are relevant. Concerning one side of this question (i.e., making significant contributions to the advancement of science),[7] a better measure is the number of citations received from peers by an author or by each article. This comes to assess the 'impact' of articles, i.e., their echo in the world scientific community. Using the SCI allows this.

The impact of Arab articles is comparatively poor: four times less than the impact of articles issued by researchers from the metropolis of science, and twice less than the impact of papers coming from a number of other intermediary countries (for example, Chile, Thailand or South Africa: mean impact 0.5; against Mediterranean countries: mean impact 0.25). Each of the Arab countries is approximately at the same level (from Morocco: impact = 0.23 to Egypt: 0.20).

One may call into question biases of the database. Nevertheless, what is interesting is that some sub-fields in each country have a greater impact. They do not always fit the most developed branches (those of specialisation). Small and dense scientific communities may thus deliver results more original than loose and well-stocked ones. This brings us back to the role of key figures and circles of specialists in the beginning of the establishment of science. The gap between impact and specialisation can be measured in each country. Figure 6 illustrates the Egyptian case.

It is of course important to identify the branches which (though not very popular, nor well known at home) shelter brilliant researchers of world repute. This is the case in Egypt for optoelectronics and signal processing or in Algeria for analytical chemistry and most unexpected ecology and biology in arid zones. On the contrary, branches of heavy specialisation may have a meagre impact like chemistry in Egypt or nuclear physics in Algeria.

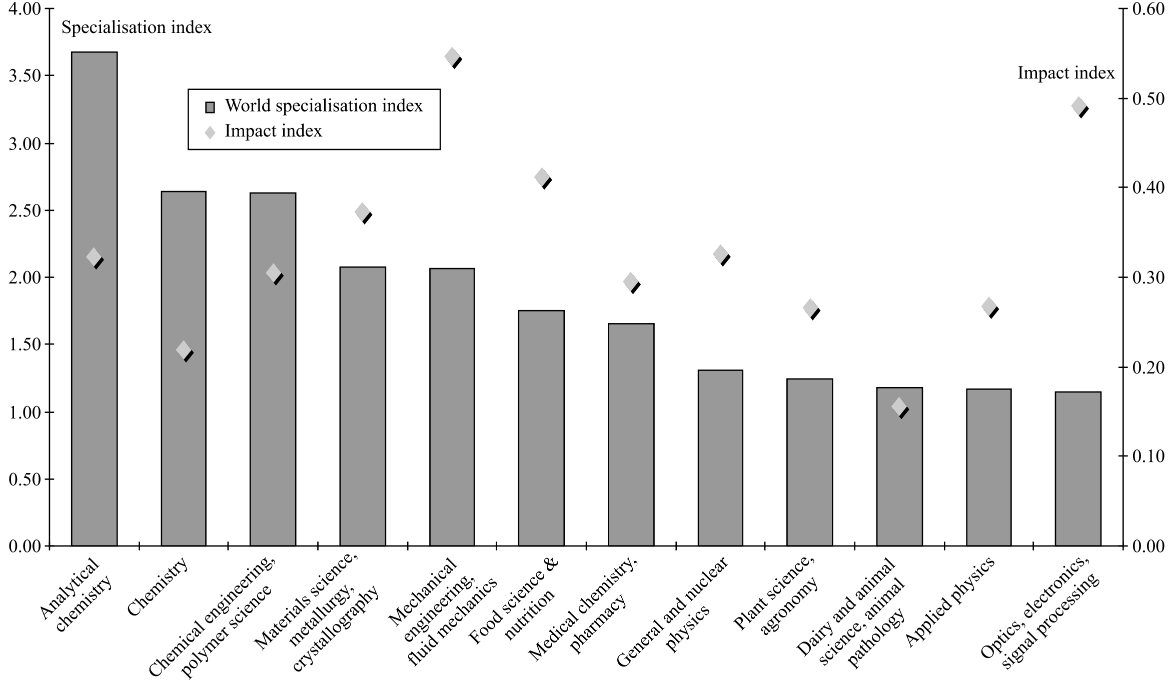
Sanctuaries for Research (Micro Bibliometrics)

All preceding data are aggregates at a country level. They do not inform the user on the loci and the actors of significant research. More can be learnt by processing the databases in detail. We set about it by marking off 100 scientific sub-fields.[8] We then identified and standardised the name of town and institution associated with the authors in their addresses; and finally we standardised the name of the (main) authors.

This sizeable work allowed us to bring to light new characteristics of the research activity. We established a hierarchy of the institutions contributing to different sub-fields and we investigated their evolution along time (national scoreboards). We searched the capabilities of the main 'research establishments' and wondered what sort of critical masses they had at their disposal. We finally brought out the leading authors; we studied their contribution to the whole production and we drew the graph of their scientific networks assessing whether they were 'provincial' or global. We extended this network approach to establishments and to the countries themselves.

FIGURE 6

Egypt: Specialisation Index and Impact Index for the Top Disciplines (2004)



Source: ISI–Thompson Scientific data, computed by OST.

The national scoreboards cross the 100 sub-fields with the main establishments of one country (generally forty of them). Not only do they give to local policy makers a synthetic view of the capabilities they may rely on but they also allow us to assess the contribution to each topic by different sorts of establishments and to identify the 'research institutions'.

The result is that production is highly concentrated in one to three establishments per country (Table 6). Research needs favourable surroundings, which indeed very few institutions are ready to offer. The rare 'research' establishments are generally universities, predominantly contributing to the largest part of the sub-fields. Most of them are public, and they were created in old times with a scientific ethos.[9] Some research centres can be noticed in their assigned sub-fields, but a majority carry out routine services or development tasks contributing little to publications. The main exceptions are in Egypt—the National Research Centre (NRC, generalist), ARC (agriculture) and the Atomic Energy Agency.

In the Gulf countries (where there is often only one large public university with good standards) and in Machreq the number of research establishments is limited to one or two per country. In Egypt and in Maghreb, the research culture is more diffused. Detailed bibliometric data show that it spreads from historical universities to newly created establishments. For example, in Morocco by 2003 establishments of the second generation (set up in 1985–95) ranked first or second at the national level in half of the sub-fields (Kleiche and Waast 2008). The same is true in Tunisia.

How is the scientific landscape changing over time? We have already pointed out that the main orientations get reinforced in each country (with its characteristic specialisation in material sciences, and under-specialisation in life sciences) and that in Maghreb the research culture somehow spread to 'young' (public) establishments. When entering into details, it turns out that the dynamics is more subtle. Morocco is a good example. Due to regulations binding promotions for faculty members to the achievement of several successive large pieces of personal work (theses), research and publication displayed strong progress during the 1980s and 1990s. When new universities were created, they attracted young and active teachers who developed sharp specialisations, while some old establishments lost ground in their past traditional fields of excellence (basic science). Over 2,000 prime movers of research (theses) began to fail as many academics reached the top of their careers and new incentives were not implemented

Table 6
Least Number of Establishments Required to Account for a Large Percentage of the Country's Scientific Production

Number of establishments…	*MA*	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*BH*	*KW*	*UAE*	*OM*	*QT*	*SAU*	*Iran*
…accounting for 50% of the country production	3	4	3	4	2	1	2	1	1	1	1	1	2	5
…accounting for 80% of the country production	5	10	5	8	3	2	2	1	1	2	1	1	5	12

Source: Academic ranking of Universities in OIC Countries, SESRTCIC, Ankara (2007).

for researchers. On the contrary, the minister dedicated to research was suppressed. As a result, the growth of output (the highest in the region for decades) bent and then reversed to a fall. The detailed analysis by sub-fields and institutions shows that after 2002 some young universities were the first to be hurt in their sharp specialisations. Three years later all the new universities were more severely hurt, old prestigious establishments began to regress and the fall concerns all sorts of fields (Appendix 2). What remains stable is either linked to 'sanctuaries' of research (Marrakech University is an example) or to the specific efforts of some key figures (brilliant researchers—Oujda or heads of establishment—Mohammadia) (Waast and Rossi 2008). This sort of situation is prevailing in Machreq. The story shows that the spread of a research culture is fragile, and its expansion raises an important problem: What is the critical mass existing in each place around a specific sub-field?

Critical Masses

We may deal with this question through another case study. We considered the two 'research universities' of Jordan (Jordan University at Amman and JUST at Irbid). We assessed their capabilities along the ten last years. Out of the 100 scientific sub-fields distinguished in our classification, fifty are present though most of them are weak. Sixty per cent of the production is concentrated in ten sub-fields and 33 per cent in four sub-fields only.[10] We identified the authors who contributed to the output and we classified them in four categories: some are 'very active', they contributed at least ten articles indexed by the SCI along ten years. Others are 'active', they contributed five to nine articles in the same period. The third category gathers 'available' academics who contributed two to four articles. Finally, 'fleeting' researchers contributed one article in the period; a number of them were probably doctoral students. The result for the four 'excellent' sub-fields in each university is given in Table 7.

Whatever the specialty, 70 per cent of the authors are 'fleeting' ones. Conversely, a very small number of active (and very active) researchers are the co-authors of 25 to 33 per cent of the output (up to 40 per cent in engineering sciences). In some sub-fields, one-third of the production rests on three to five persons (civil engineering at JUST, energetic engineering at JUST and Jordan). Such talent could well be considered as 'treasures' by

Table 7
Number of Authors in Noteworthy Specialties, JUST and Jordan University (1996–2005)

	JUST				*JORDAN*			
Number of authors…	*Pharmaco-toxicology*	*Energetic engineering*	*Civil engineering*	*ICSTs*	*Pharmaco-toxicology*	*Energetic engineering*	*Chemical engineering.*	*Solid physics*
…Very Active	3	5	2	0	1	5	2	2
…Active	6	5	6	6	11	1	5	1
…Avalable	45	17	22	27	25	14	14	29
…Fleeting	129	70	77	86	123	46	42	57
Total authors	183	97	107	119	160	66	63	89

Source: Rossi and Waast (2007: 49–51). Data = PASCAL database.

their university and country. In return, the preservation of strong points is fragile. The replacement of withdrawing stars is delicate and the renewal of topics by newcomers is uneasy. If a new pole of development appears elsewhere it may well cut into the 'critical mass' that existed in some historical previous site.

Even in 'research universities' (as JUST or Jordan may be called), no more than thirty or so researchers can be considered as 'very active', and 100 as 'active'; the staff ever so slightly motivated is around 300 persons (out of 1,500 faculty members). A study commissioned by the Organisation of the Islamic Conference (Serstic 2007) came to similar conclusions. It shows that the ratio of articles to the number of faculty members varies highly between universities; there are also very different norms according to the countries. While leading universities in Iran or Turkey have ratios close to those of the developed countries, the norm is half of that in the 'research universities' of the Arab world (Gulf and Machreq) or even less (one-fourth in Maghreb and one-tenth in Egypt). Moreover, there is a deep gap between one or two universities and all others (which have minute ratios). This has mostly to do with the capacity of universities to mobilise their staff for research. It may be said that there is a large potential remaining to be tapped. But adequate incentives need to be put forward.

Networks

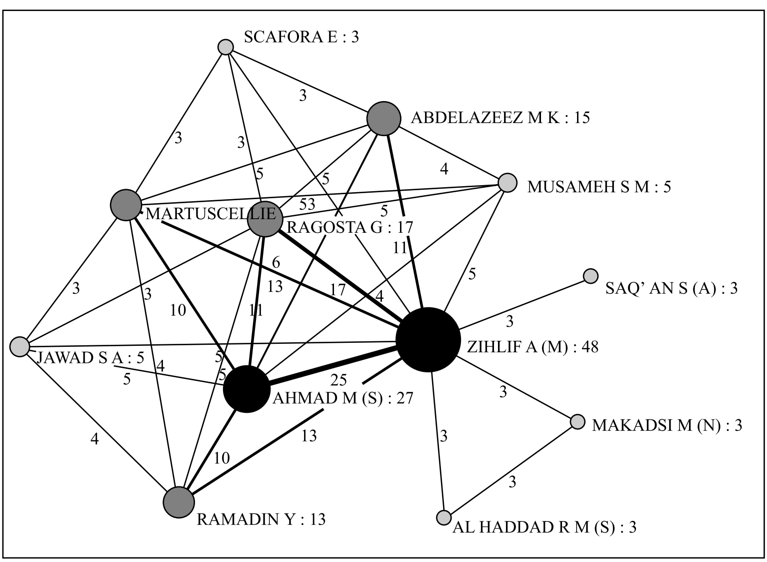
Considering the important role of key figures, we took an interest in their networks as they may reveal the structure of the scientific community. We studied their co-authorship and we drew the corresponding graphs. We also drew the graphs of co-authorship concerning the members of an establishment, and those of a country. Some features are noteworthy.

At a personal level, the authors work mostly in twos or threes with colleagues from the same establishment. They sometimes maintain a long-lasting collaboration with one or two foreign partners. Rarely do they participate in a web of international co-authorship (pointing out to a world programme, as does a Moroccan network involved in the ATLAS high energy project of CERN, Europe). Rarely too are networks developing long national chains (as once in Algeria around a key figure of electronics). The general pattern is that of a 'laboratory', built around a few tenacious pillars and which must be preserved at all costs. It is the building brick of sustained research work and the fallback position when supports threaten to withdraw. Regional and international collaborations exist but they generally last the average span of a project life: They are not very visible in the graphs (which record long-term collaborations). Figure 7 gives an illustration for Jordan.

When investigating the graph of collaborations involving one specific establishment, the 'laboratories' related to its main specialties are the diagrams that stand out, together with some less active binomials and a crown of (foreign) partners. These foreign partners are connected one-to-one to the laboratories, but generally not inter-connected; nor connected to other institutions in the country. This suggests that cooperation results from initiatives of the laboratories (and their key figures), rather than from voluntarism of the university. It suggests also that universities (and laboratories) are anxious to keep 'exclusive rights' on their (foreign) partnerships.

Figure 7
Main Collaborations of Jordan University, 1987–2003: Simplified Diagram

Civil Engineering



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Energetic Engineering
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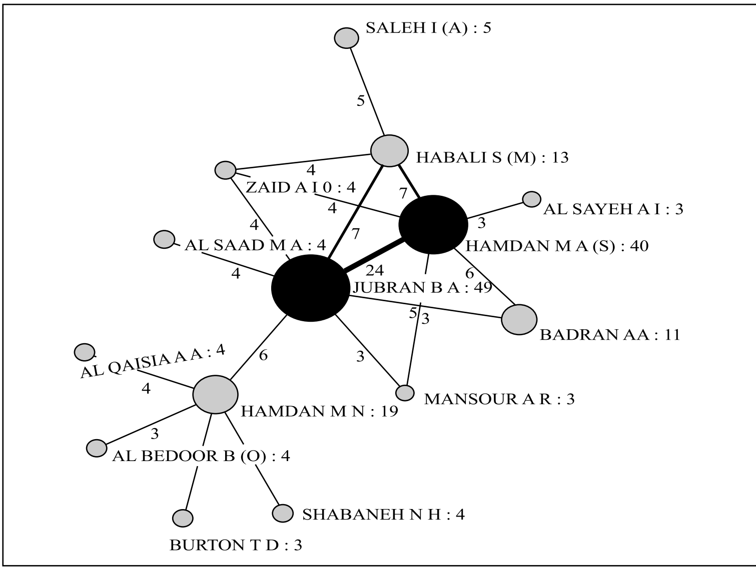
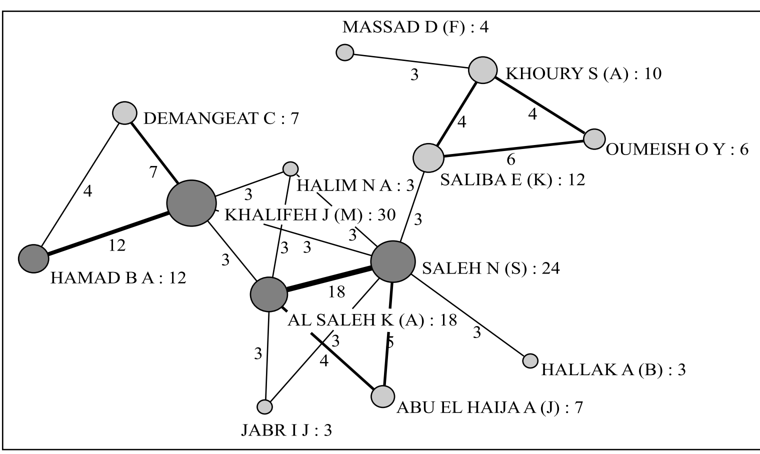


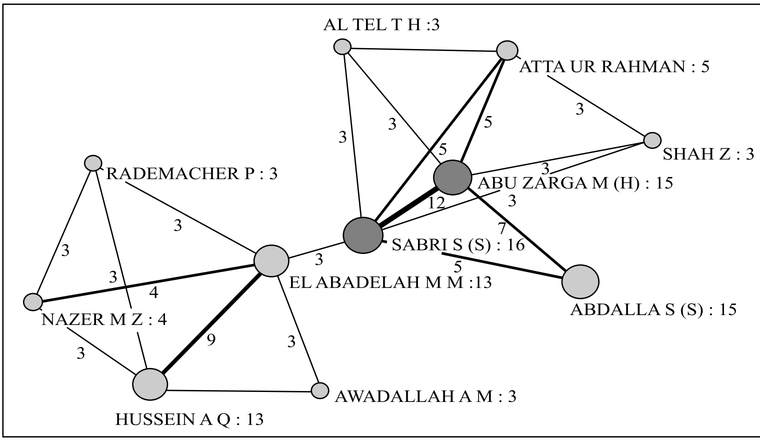
Physics
(theoretical + solid state + thermodynamics)



(*Figure 7 continued*)

(*Figure 7 continued*)

Pharmacology



Source: PASCAL; processed by P.L. Rossi.

Note: Thickness of line depends on the number of co-authorships. Minimum link: 3 co-authorships. Bowls represent authors. Colour and size of bowls are function of the total number of their publications (Dark grey = more than 30 articles; Light grey: 10 to 30 articles). With such restrictions, the graph of Jordan University is limited to the 4 diagrams above, relating (from top down) to: civil engineering (materials); energetic engineering (solar, refrigeration); physics (theoretical, solid, thermodynamics); and pharmacology (1 team of chemists + 1 of biologists). With less restrictions, links would appear between energetic engineering and physicists + mathematicians (not shown here). Four long-term international collaborators are present in civil engineering and in physics.

Finally, when investigating the graph of collaborations involving the institutions of one country, the diagram is structured by the links that the 'research universities' generate. This is all the more evident when there is a strong gap between these universities (in small number) and other establishments. Jordan is an example of this case. There are few relations involving Universities other than the two main ones (Jordan and JUST). International relations are little oriented toward Arab countries and rather toward Europe and the US (both universities). There is no sign of teams taking part in large international programmes, linking several countries of the region and beyond. Though rare, such ambitious projects can be identified elsewhere (Algeria + Morocco + Tunisia and European countries about genetic diseases, several Mediterranean and European countries about irrigation and around WHO programmes about schistosomia). It may be that our Jordan graph is too simplified to bring them out.

These features apply well to the Gulf and Machreq countries. In their case, the role of research universities is crucial to structure research at the country level. Their strengths and initiatives (partnerships), or those of their main laboratories and key figures orient national capabilities and ensure the maintenance of scientific updating. In Maghreb and in Egypt, the dynamic is more complex. In Algeria, the few research establishments (especially Algiers' University of Science and Technology, USTHB) helped in launching numerous young universities in their region and they keep links with them. In Morocco, the gap is not too large between the first historical establishments and the new generation of universities. Research blossomed in both (at least in a number of sub-fields) and there are webs of relations between all of them, each linked to a discipline and showing the germs of scientific communities. In Tunisia, the country's structure is linked to accredited 'national laboratories and units', and internal links also foreshadow scientific communities in specific fields. The Egyptian graph is luxuriant and multicentric. Key figures and laboratories play a role; each one has its initiatives (and foreign partners). Some big centres seem to manage long-lasting strategies (longer and more stable chains of links); universities are more driven by opportunities; state initiatives seem to aim at the setting of sizeable establishments rather than at backing networks between many teams in the country.

Conclusion

What bibliometrics brings out is a situation of change with strong contrasts in the Arab region. Since two decades there has been a general trend of growth, at different paces. Beginning with almost invisible scores, the Maghreb zone has sustained a high rate of increase—the highest on the African continent so that its main countries (Tunisia, Morocco and Algeria in this order) hold now the honour seats in this continent as well as in West and Centre Asia.[11] Conversely, the Machreq and Gulf countries dawdled for long (except Jordan), or rather recorded advances and retreats up to the last five years. Kuwait and Lebanon are the most striking examples. War had noxious effects in their case. Egypt is the 'giant in the region'. Science was institutionalised here more than a century ago, a number of universities had for long good repute and foreign cooperation never lacked. Nonetheless, there may still be ups and downs: There was a serious 'air pocket' in output during the decade of 1995–2004, before the scores rose again.

Of course, these contrasts have to do with policies and budgets. Evidently, wars have had deep injurious effects (Lebanon and Kuwait, but much less in Algeria). Of course, efforts of the state to institutionalise science are powerful stimuli (Maghreb countries and Egypt, contrary to Machreq and the Gulf) and sustained public funding is a major asset (Tunisia). But the link is not so direct. Ups and downs in output and in support of the state are not always in phases. Ups and downs in the output and in the support of the state are *not always in phase*. For example, the production grows consistently in Algeria when suddenly after 1995 research receives funds aplenty from the government after a decade of starvation. But the results do not match the wavering of state support in Morocco, where the output grew rapidly first with almost the only help of cooperation, and bent just after a wilful ministry took great care of research, to such an extent that vigorous measures (under announcement) have now to be taken up to try and restart the production (new structures, incentives, evaluation and extensive funding).

Even the peculiarities of specialisation, which are a second important feature of the Arab countries, is a mean reproducing through twisting paths. We recorded that all the countries have remarkable affinities with mathematics, and a high specialisation in engineering (resting in North Africa on solid bases in physics and chemistry including theoretical aspects). Conversely, under-specialisation is noticeable in natural sciences (including geosciences, though geology is sometimes well developed), especially in life sciences (notably, fundamental biology and its modern tools like biomolecular biology are weak). But it is not easy to understand why, within these great specialisations (which are strengthening) some niches rather than others are filled and how they evolve through time. We saw, for example, that when there was a retreat in Morocco, the first hit sub-fields were those which had recently developed in rather less dedicated universities. Or that in Egypt, in a period of general growth of output, and though the country keeps the largest capabilities of the region in most of agricultural sciences, there was a decline in a number of agriculture sub-fields (except very few, linked to special recent projects) (Appendix 3).

Understanding these discrepancies needs more studies of another nature. But micro bibliometrics is of some help to catch hold of the instability of results. It shows a few important features.

The first one is that Arab countries have yet a great margin to enrol their potential in research. The ranking of OCI (Serstic 2007) shows that their establishments mobilise their staff three to four times less than top universities in Turkey or Iran. Our micro bibliometric calculation shows that in each country the bulk of research is produced by a very few 'research establishments'; and even in these ones, only one out of five to ten staff are really dedicated to research work. This ends up in problems of critical masses and the following ones of transmission and succession.

The second feature appears through the description of networks. Most of them are concentrated in small groups, with short networks and little participation in wide ranging international programmes. This means that a major objective remains to preserve the stronghold of a laboratory, generally through numerous small projects in cooperation with a variety of mid-scale partners, rarely with ambitions of breakthroughs at the regional or world level.

The last feature is that there are few signs of scientific communities being built, and depicted in long local chains or webs of co-authorship at the local or regional networks.

Appendix 1
Noteworthy Specialisation in Scientific Areas: Some Arab Countries (Comparison to the World)

A. Material Sciences

	DZ	*MA*	*TN*	*EG*	*JD*	*LB*	*SY*
Mathematics and statistics	**1.87**	**2.99**	**3.38**	1.09	0.8	1.43	NS
Nuclear and general physics	**2.32**	1.46	0.44	1.31	0.76	1	NS
Applied physics	**2.58**	**1.81**	**1.96**	1.17	0.64	NS	NS
Materials, cristallography, metallurgy	**2.35**	1.41	1.42	**2.08**	0.34	NS	NS
Analytical chemistry	1.29	1.24	1.25	**3.68**	1.04	NS	NS
Medical chemistry, pharmacology	0.44	1.49	0.19	**1.65**	**1.9**	NS	NS
Mechanical engineering	**2.74**	1	1.22	**2.07**	**3.81**	1.1	NS
Chemical engineering, polymers	**2.61**	0.56	0.93	**2.62**	**1.83**	NS	NS
Opto electronics, signal processing	**2.16**	0.63	1.1	1.15	1.12	0.77	NS
Computer science	1.25	0.87	0.84	0.76	1.11	1.13	NS
Physical chemistry, spectroscopy	0.82	0.91	0.65	0.76	0.52	NS	NS
Astronomy, astrophysics	0.35	0.3	0.02	0.21	NS	NS	NS

B. Life Sciences

Ecology, environment	1.12	1.1	0.98	0.79	1.55	0.9	0.32
Plant science, agriculture	0.62	1.57	0.95	1.25	**2.06**	1.1	1.83
Cattle breeding, zoology, veterinary science	0.38	0.9	1.56	1.18	**1.61**	NS	NS
Food science, nutrition	1.06	0.54	0.53	**1.76**	1.46	NS	NS
Microbio, virology, infectious diseases	0.24	0.74	1.37	0.81	1.26	0.93	NS
Oncology	0.09	0.13	0.19	0.3	0.24	0.83	NS
Endocrinology and reproduction	0.47	0.16	0.7	0.39	0.3	**1.6**	NS
Internal medicine	0.21	0.44	1.59	0.12	**2.23**	0.8	NS
Gastro enterology and cardiology	0.12	1.39	0.88	0.47	0.3	**2.4**	0.16
Epidémiology, public health	0.24	0.69	0.9	0.72	1.18	**2.04**	NS
Biomedical engineering	0.82	0.9	0.79	0.45	**1.7**	**1.71**	NS
General biology	0.32	0.61	0.81	0.24	0.08	NS	NS
Biochemistry, molecular and cellular biology	0.18	0.25	0.42	0.28	0.2	NS	NS
Immunology	0.03	0.14	0.61	0.11	NS	NS	NS
Genetics	0.44	0.24	0.91	0.07	0.56	NS	NS
Neurosciences, neuropathology	0.06	0.31	0.44	0.09	0.14	NS	NS
Medicine: other specialities	0.21	0.61	0.12	0.36	0.28	NS	NS

Source: Data SCI (OST Proceeding for ESTIME) (2003).

Notes: **World norm = 1.** In **bold** letters: hyper specialisation; Clear filling: under-specialisation; NS = non-significant.

A specialisation index of 2.00 (e.g. in one country in mathematics) means that the proportion of publications in mathematics to all the publications in this country is twice the proportion of mathematics in the world production of science.

Appendix 2
Scoreboard: Evolution of Production in the Main Establishments of Morocco: Four Periods (1996–2007)

	Sc agric				*Sc bio*				*Sc med*				*Math*			
U Rabat Souissi	3	8	8	4	4	4	9	13	306	552	616	405	0	0	0	0
U Marrakech	27	53	70	52	36	67	53	35	5	30	37	36	27	34	56	53
Hop Univ Casa	0	0	0	0	0	1	5	4	360	437	396	333	0	0	0	0
U Rabat Agdal	11	36	31	28	12	30	29	20	6	33	34	17	2	18	31	23
U Casa Chock	4	11	22	9	9	18	17	14	16	52	49	56	3	12	18	9
U Hassan 2 (Msik & Mdia)	1	9	11	9	3	11	18	16	1	16	10	15	2	9	2	7
Hop Mili	0	1	0	0	1	1	0	7	50	86	172	128	0	0	0	0
U Oujda	7	5	9	6	9	8	6	4	3	16	7	14	2	8	10	10
U Fes	9	14	25	14	12	23	26	21	3	16	26	35	5	11	12	5
U Kenitra	14	31	19	16	4	10	8	14	4	9	16	10	2	7	17	7
U Agadir	8	11	21	18	8	14	11	11	0	10	5	3	2	1	2	9
U Tet_Tanger	1	7	8	10	4	10	8	18	2	9	6	7	5	6	6	4
U Jadida	10	18	18	16	6	19	19	15	3	12	10	7	1	4	4	2
Ecole ENS	2	7	14	8	1	5	4	4	1	3	5	11	10	9	5	6
I_Agr-Véto	44	47	47	39	18	14	18	18	9	19	12	11	1	0	0	0
U Meknes	7	11	22	6	11	9	18	8	2	3	5	2	2	3	15	3
R&D Ind.	2	5	2	5	0	7	5	11	1	0	4	4	0	0	0	0
Ecole Ingén EMI	7	10	9	4	1	0	1	0	0	0	0	0	2	3	6	2
I Pasteur	0	0	1	1	3	1	2	7	17	18	13	11	0	0	0	0
I N Rech Agr	15	25	18	10	3	2	2	3	1	1	0	0	0	0	0	0
Ec Agri Meknes	13	14	9	6	0	3	2	1	0	0	0	0	0	1	1	0
Total	210	279	318	240	144	234	247	246	838	1318	1468	1205	74	140	207	137

	Physique				*Chimie*				*Scing*				*TOA*			
U Rabat Souissi	1	1	1	1	0	0	1	2	0	1	2	1	0	0	0	0
U Marrakech	59	68	71	75	15	24	10	12	32	67	70	99	33	65	44	37
Hop Univ Casa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
U Rabat Agdal	47	123	79	48	5	18	17	12	31	54	59	55	17	41	26	26
U Casa Chock	29	59	43	34	4	10	5	12	21	28	36	45	2	11	8	8
U Hassan 2 (Msik & Mdia)	11	41	47	24	1	10	45	44	4	11	20	35	2	5	10	8
Hop Mili	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
U Oujda	5	34	28	44	6	5	5	5	9	19	22	45	4	25	9	9
U Fes	32	53	51	20	8	17	13	2	18	48	46	18	11	21	7	2
U Kenitra	13	32	74	22	8	7	15	8	14	29	42	34	4	21	10	5
U Agadir	34	70	28	31	11	18	14	8	8	14	18	24	8	17	13	8
U Tet_Tanger	8	17	31	27	1	5	8	17	4	16	21	17	7	12	7	7
U Jadida	13	61	37	24	8	17	11	9	10	29	32	18	3	14	11	9
Ecole ENS	8	28	38	17	4	5	9	11	10	21	26	21	4	2	2	2
I_Agr-Véto	0	0	0	0	0	0	0	0	10	10	8	4	7	8	0	5
U Meknes	21	63	48	26	10	14	4	3	6	30	12	9	11	26	24	5
R&D Ind.	0	0	0	1	0	0	0	0	2	7	8	8	7	22	3	4
Ecole Ingén EMI	3	9	14	7	3	4	0	3	14	22	11	10	0	1	3	1
I Pasteur	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
I N Rech Agr	0	0	0	0	0	0	0	1	0	1	1	2	0	3	0	1
Ec Agri Meknes	0	0	0	0	0	0	1	2	0	0	0	0	2	1	0	0
Total	285	582	512	361	88	143	159	143	223	408	426	423	142	260	185	135

Notes: Period 1 (left column): 1996–98; Period 2: 1999–2001; Period 3: 2002–04; Period 4: 2005–07.
Disciplines: Sc Agric = Agriculture; Sc Bio = Biology; Sc Med = Medicine; Chimie = Chemistry; Sc Ing = Engineering; TOA = Earth, Ocean and Atmosphere.
Shades of grey go darker when there is a growth in publications and lighten when there is a decrease.

Appendix 3
Agriculture Sciences: Mediterranean Countries, Evolution 2001–03 (Number of References)

	Algeria	*Morocco*	*Tunisia*	*Egypt*	*Lebanon*	*Jordan*	*Syria*	*Palestine*
Hydrology	39	**75**	41	28	20	32	Ns	14
Irrigation	NS	NS	**8**	NS	NS	NS	NS	ns
Soil Sciences	24	**52**	25	28	Ns	21	ns	ns
Farming methods	ns	**27**	16	24	Ns	15	15	ns
Plant breeding	14	**60**	43	36	Ns	22	45	ns
Food processing	17	47	70	**141**	Ns	27	ns	ns
Cattle rearing	ns	ns	**17**	13	Ns	Ns	ns	ns
Entomology	10	33	20	**55**	Ns	Ns	20	ns
Biochemistry	ns	ns	ns	**14**	Ns	Ns	ns	ns
Molecular Biology	ns	ns	**18**	10	Ns	Ns	ns	ns
Microbiology	ns	47	57	**75**	Ns	17	ns	ns
Genetics	ns	ns	**11**	Ns	Ns	Ns	ns	ns
General Biology-Physiology	ns	ns	ns	**11**	Ns	Ns	ns	ns
Plant Physiology	ns	24	18	**56**	Ns	Ns	ns	ns
Zoology	10	16	**31**	20	Ns	Ns	ns	ns
Animal Physiology	16	24	21	**43**	10	Ns	ns	ns
Ecology (Fundamental)	25	**63**	35	37	Ns	Ns	ns	ns
Ecology (Applied)	12	36	22	**53**	Ns	Ns	ns	ns
Biotechnology: methods	ns	9	20	**36**	Ns	4	ns	ns
Biotechnology: strategic	ns	ns	ns	**9**	Ns	Ns	ns	ns
Biotechnology: industrial	ns	19	ns	**27**	Ns	Ns	ns	ns

Source: PASCAL; Processing P.L. Rossi.

Notes: Figures are the scores for 2003. In **bold** letters: maximum regional score.
Evolution from 2001 to 2003: Light grey = progress; Dark grey = regression.

NOTES

1. This assumes that the scientists have a 'Mertonian' ethos (Merton 1973), and their main objective in life is to publish fresh discoveries to be reviewed by their peers. Nevertheless, bibliometrics is in no way an evaluation.
2. SCI non-expanded for the sake of chronological comparisons over a long period of time. SCI is a product of Thomson Scientific, USA. PASCAL is a product of INIST, CNRS, France.
3. Twenty years ago (in 1989), the number of references in SCI was 966 for South Korea, 485 for Singapore, 357 for Thailand and 131 for Iran.

TABLE 1
Enrolment in Tertiary Education

	MA	*DZ*	*TU*	*EG*	*JD*	*LB*	*SY*	*Bhr*	*KW*	*UAE*	*OM*	*Iran*	*Chile*	*Thaïland*
Enrolment 3ry Edu (% of age group)	13	20	26	29	35	48	Na	34	22	22	13	24	43	41
Women (% of total enrolment)	46	51	55	46	51	52	Na	63	71	61	56	51	48	54

Source: UNESCO, UNDP: Human Development report (2007–08).

4. Not to mention Iraq.
5. This is absolutely opposite to the rest of Africa south of Sahara, where (except for South Africa) the capabilities are concentrated in agriculture and health, very little in engineering and material sciences.
6. The US has sustained substantial capacity and institution building in the region, notably in agricultural sciences.
7. The other side is of course socio-economic relevance. This can be measured by a quick capture of the results by users. Unfortunately there are few systematic data on this point.
8. A more detailed breakdown would also be possible. But attention should be paid to the need of having numbers high enough in each box when crossing the sub-fields (with for example, institutions, which are also numerous). This too is the reason why we assembled publications by periods of four years, for the yearly product in certain sub-fields may be irregular. These choices were decided after a trial and error process, trying to accommodate the characteristics of all the countries.
9. For most of their followers, research became 'a subordinate function'.
10. These dominant areas are pharmacology and energetic engineering + civil engineering and ICTs at JUST; and pharmacology and energetic engineering + chemical engineering and solid physics at Jordan. Other sub-fields with noteworthy and regular contributions in these two universities are thermodynamics, general chemistry, pollution; geology, soil science, plant breeding; and infectious diseases. This is a general pattern: in all universities of the region, one-third of the output concerns about five sub-fields, and half of the output deals with ten sub-fields.
11. They rank just after South Africa and Egypt in Africa.

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