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DRAFT GLOBAL SYNTHESIS REPORT

Study on National Research Systems
A Meta-Review

Johann Mouton & Roland Waast

Symposium on Comparative Analysis of National Research Systems
16-18 January 2008, UNESCO, Headquarters, Paris, France

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PREFACE

The authors wish to acknowledge the support and assistance of many individuals who have made this study possible.

Our first acknowledgement must go to our colleagues across the globe who have contributed directly and indirectly to the 52 country studies that have been compiled. The individual authors of each country study are listed in the country compilations and in the regional reports, but a special thanks is due to: Daniel Villa-Vicencio, Venni Krishna, Jacques Gaillard and Rigas Arvanitis for their contributions.

Johann Mouton wishes to specifically mention the assistance and contribution of the researchers at CREST (Nelius Boshoff, Simone Esau and Frank Teng-Zeng) as well as the substantial support by other staff members: Cornelia Jacobs, Lynn Lorenzen, Charline Mouton, Astrid Valentine and Annemarie Visagie. - and a special word of thanks to Marthie van Niekerk who assisted with the final editing of the compilations.

Roland Waast wishes to acknowledge the assistance of Renée Ribier who was of great help in the analysis of the Latin American cases, and Florence Verlhac, who undertook complementary research on the web, summaries and the translations of background papers mainly for African countries. My colleagues at IRD working for the ESTIME project were of great help regarding the Arab countries. Special thanks to Prof. Hocine Khelfaoui for the communication of previous and recent interviews and analyses for Algeria, Burkina, Ivory Coast and Cameroon.

Finally, the authors also wish to extend their immense gratitude to the staff of the Higher Education Forum Secretariat at UNESCO with whom we have remained in constant liaison over the duration of the project: Marie-Louise Kearney, Asa Olsson and Mary Rosset.

5 January 2008
Johann Mouton (Stellenbosch)
Roland Waast (Paris)

SECTION 1: INTRODUCTION

1.1 THE BRIEF

At a workshop held on the 6th and 7th of April 2006 at UNESCO, Paris, the objectives of a proposed study on national research systems were reconfirmed as follows:

> *….to learn more about research systems in developing/poor countries, and to help strengthen research and research capacity. Thus, the project supports research on and for development so that developing/poor countries may articulate and have ownership of these systems which are key assets for their development.*

At a subsequent meeting, it was decided that a "follow up group be established (consisting of) Dr Mouton, CREST/South Africa, Dr Roland Waast IRD/Paris, Dr Lazar Vlasceanu UNESCO CEPES/Romania, Dr Carthage Smith ICSU/Paris with support to be given by Dr Christina von Furstenberg (Social Sciences) and Dr Tony Marjoram (Science) who are members of the UNESCO Forum Coordinating Committee. It was also decided to invite Drs Mouton and Waast "to undertake a literature search of major reports on the subject of National Research Systems, dividing the task according to their areas of experience". And finally, it was suggested that "a report on the findings of this search /mapping exercise be presented at the UNESCO Forum's Global Colloquium (29 November – 1 December 2006) which would deal with current challenges for universities (especially in developing countries) as part of national research systems".

In further reflection on this Brief, the authors decided to refer to this study as a meta-review of existing country studies as the request goes beyond a standard review of the literature. A meta-review (or systematic review) is a study which has both a descriptive and "evaluative" aim. Its descriptive aim is to describe and summarize in sufficient detail the key elements of a particular study (i.e. date, coverage, study objectives, data sources, methodologies used and key findings). In addition it usually also has an evaluative aim, that is, to make a judgment on the quality of the study being reviewed. This would entail commenting on the reliability and recency of data sources, appropriateness of design and methodology as well as the extent of the coverage of the study.

The further clarification and elaboration of the Brief entailed a number of decisions around the demarcation of the studies. Two were paramount: the matter of time and the selection of countries to be included in the Meta-review.

Dateline

We proposed to review studies that had been published between 1990 and 2005. We would ideally have liked to confine this review to studies over the past 10 years only. However, we believed that – given the focus on poor and developing countries (cf. below) – that we might in some cases come across studies published in the early nineties only.

Selection of countries (and regions)

In the final selection of the list of the countries, we employed the following criteria for inclusion:

- The developing and poor countries of the world
- Non-OECD countries and also not including the newly industrialized countries
- Countries that have not already been well researched even if they fall into the two categories above[1]
- Countries with at least some minimal R&D capacity

The final criterion was included, for two reasons; (1) given the focus of the overall project on assisting countries with poorly or underdeveloped R&D (and S&T) capabilities, we thought it would be reasonable to begin with those countries where such a minimal capacity exists; (2) for pragmatic considerations in order to keep the number of country studies for this review manageable. The inclusion of this criterion implied that one has some way of operationally define R&D capacity. Although we are aware that this is not an uncontested decision, we have decided to take the annual number of publications in the ISI Web of Science as a criterion and only to include countries which have produced at least 200 scientific papers over the 3 years period (2002 – 2004)[2].

This criterion produced the following list of countries to be included in our review.

[1] These would then rule out countries such as China, Brazil, India and South Africa

[2] We have selected this rather low cut-off point keeping in mind that a significant proportion of the research and scholarship produced in these countries does not appear in journals indexed in the ISI. Bibliometric data provided by Dr Robert Tijssen, at CWTS, Leiden.

African Region

BENIN, BOTSWANA, BURKINA FASO, CAMEROON, ETHIOPIA, GABON, GAMBIA, GHANA, IVORY COAST, KENYA, MALAWI, MALI, , NIGERIA, SENEGAL, , TANZANIA, , UGANDA, ZAMBIA, ZIMBABWE,

Arab Region

ALGERIA, BAHRAIN, EGYPT, IRAN, JORDAN, KUWAIT, LEBANON, MOROCCO, OMAN, SUDAN, SYRIA, TUNISIA, U ARAB EMIRATES

Asia Region

BANGLADESH, INDONESIA, MALAYSIA, NEPAL, PAKISTAN, PHILIPPINES, SINGAPORE, SRI LANKA, THAILAND, VIETNAM,

Latin American and Caribbean Region

ARGENTINA, BOLIVIA, CHILE, COLOMBIA, COSTA RICA, CUBA, ECUADOR, JAMAICA, MEXICO, PANAMA, PERU, TRINIDAD & TOBAGO, URUGUAY, VENEZUELA,

After this initial selection process we subsequently – as we proceeded with the collection of country studies and other data – discovered that we could not find any studies for those countries underlined above. Because the biggest impact would be on the Africa region, we finally decided to substitute four new countries in the place of those that we could not cover in this review. We, therefore, included in the Africa meta-review the following 3 countries: Lesotho, Namibia and Rwanda. In our selection of countries in the Arab region, we also managed to include one country study (Qatar) in the place of Egypt and Iran that could not be covered. No changes were necessary for the final countries selected for Asia, while we could not include a study on Uruguay in the final compilation for Latin America. In summary, our study compiled 52 country reviews:

- Africa (17 countries)
- Arab region (12)
- Asia (10)
- Latin America (13)

1.2 RESEARCH DESIGN AND METHODOLOG

Given the large number of countries to be covered as well as potential diversity of studies to be reviewed we adopted a two phased approach:

- Phase 1: Utilizing the knowledge and resources of a small number of research co-workers to collect relevant material and complete a first round of study mapping (the collection and mapping phase).
- Phase 2: Comparative and integrative review of the first round study maps by ourselves (the integrative review phase).

Phase 1: The collection and mapping phase

Based on previous studies and collaborations we were able to call upon a number of knowledgeable and well-placed researchers to assist us in the execution of this commission. Most notably we were able to secure the collaboration of Daniel Villa-Vicencio (Mexico) and Venni Krishna (India) and their collaborators to assist us with the compilation of the Latin America and Asia country reviews respectively. Their key tasks were twofold:

- To work through available and known collections of studies as well as systematically summarize all possible sources of information (government resources/ websites/ S&T studies centres) in order to identify studies that meet the criteria for inclusion as outlined above.
- To produce a summary "map" of each study in accordance with a framework which we have developed (cf. below).

In addition to being able to call upon the co-operation and resources of these two persons, we were also able – especially with regard to the country reviews in Africa and the Arab region – to optimize on recent and current studies being undertaken by ourselves and immediate colleagues. Three such studies are noteworthy:

- The first was a project, funded by the South African Department of Science and Technology. This project supported the work of scholars at CREST and High Impact Innovation and enabled us to compile a total of 22 country profiles. Fourteen of the country studies included in our compilation of 17 studies were therefore co-funded under this joint project.
- The second is the *Science in Africa* project co-ordinated by Roland Waast and Jacques Gaillard with funding from the European Commission and the French Ministry of Foreign Affairs at the end of the 1990s. The latter produced 14 country profiles of which three in particular were used in the present project (Burkina Faso, Cameroon and Cote d'Ivoire, all of them drawing from fieldwork by H. Khelfaoui and also of J. Gaillard for Cameroon). The complete set of original reports from this project is available at www.ird.fr/science/dss.
- The compilation on the Arab region benefited greatly from the fact that the work on a few country profiles corresponded with an initiative supported by the European commission which had similar objectives: the *ESTIME* project (Evaluation of Scientific and Technological capabilities in Mediterranean countries) coordinated by Rigas Arvanitis aiming at the description of the scientific and technological capabilities in 8 research partners countries of the Mediterranean (Morocco, Tunisia, Algeria, Egypt, Lebanon, Syria, Jordan and Palestinian Territories). In particular, the Estime reports on Jordan and the Lebanese Republic authored by Pénélope Larzillière and Jacques Gaillard respectively are reproduced in full in the

present compilation. The English reports from the ESTIME project are available at www.estime.ird.fr .

In the final analysis, it is very evident that we would not have been able to complete this project in the degree of detail achieved if it had not been for the fact of these other initiatives that we could build on and benefit from.

Phase 2: The integrative review phase

In the compilation of the 52 country reviews, we requested our various collaborators to comply – as closely as possible – with a framework that we had developed for the purposes of this study. This framework comprised the following elements:

- Some considerations about the History of science in the (country, region) under review
- The governance of science in the country
- Available policies (especially S&T and R&D)
- R&D performers (Establishments/ Institutions)
- Informal S&T structures (Academies, Associations, Trade unions, Journals, etc = Scientific Community)
- S&T Human Resources (Description + Considerations about the Profession of researcher: status, salaries, etc)
- Research Funding (Public or private; National and international; Trends)
- Research Output
- Scientific co-operation and agreements (Description: formal agreements; main partners (measure through bibliometrics); doctrines, practices and evolution; types and amount of funding – if available). Local collaborations (scientific and socio-economic).

Given the specific origins of the various country reviews and the fact that some studies had been completed under different terms of reference, not all of our country studies managed to comply with the framework provided above. It is also the case that even where it was possible in theory to comply with this framework, the available data and statistics would not allow for full "compliance". The end result is that our 52 country studies conform to varying degrees (and with different emphases) with the framework outlined above.

Once the 52 country reviews had been completed we commenced work on four integrative and summary Regional reports and this final Synthesis report. The four Regional Reports (Arab and Latin America reports written by Roland Waast and Africa and Asia reports written by Johann Mouton) are available under separate cover.

It is important at this stage to flag a very important methodological (even philosophical) constraint that influenced the production of the regional reports as well as this synthesis report.

In an ideal world, studies on national research systems will be produced by scholars who are deeply familiar with such systems. In anthropological terminology this is referred to as the "emic" perspective which means that the scholar looks at the "object" of his or her investigation from the inside – as someone who is indeed a member of the system that is being studied and interpreted. The "emic" perspective (in contrast to an "outsider" or "etic" perspective) implies a deep immersion in the "object" of study and therefore an intimate understanding not only of the visible and statistically measurable features of the object, but also the more interpretative, symbolic and tacit elements thereof.

The best country studies in science and technology are therefore invariably produced either by indigenous scholars who have a "lived" and insider experience of such country systems or by external scholars who have devoted significant periods of investigation in that country.

In this project the final country reviews range on a continuum from "emic" to "etic": from studies produced by authors who live in the country concerned and know it intimately to authors who had to rely on available reports, documents and statistics on the country but would not claim to have an "intimate" and first-hand knowledge thereof. This same "constraint" clearly also applies to us as authors of the regional reports and this Synthesis report. In some cases we could write from the vantage point of having visited the countries concerned; in many cases not. We comment on this point in more detail in the respective Regional reports.

However, the reader should of course keep in mind that our Brief only required a meta-review of existing studies. Our commission was to collect, standardize and compile 52 country studied using a standardized framework so as to enable us to draw some preliminary conclusions about these research systems. In addition our Brief was also to utilize the information gained through this exercise in order to construct a new Country Template that could be used in future in-depth country studies. We, therefore, do not regard this constraint as in any way invalidating what we have produced. In fact, it highlights some of the epistemological and methodological challenges that a comprehensive venture of this nature inevitably faces.

1.3 THEORETICAL ASSUMPTIONS AND OTHER APPROACHES

Various approaches to the study and "measurement" of national research systems have been developed and applied over the past fifty years[3]. These include studies commissioned or conducted by various agencies: OECD, UNESCO, UNCTAD, IDRC and IRD to mention the most prominent. These "measurement" or – perhaps more apt – "review" systems differ in terms of core ontological assumptions, theoretical models, review purposes and dominant methodologies. We elaborate on each of these points.

Ontological assumptions about unit of analysis: What "object" is being reviewed in a country review? Each approach makes assumptions about what counts as "science and technology", Research and Development, which scientific fields to be included; whether to include only formal and institutionalized science or also more informal arrangements and so on. These assumptions are often determined by the set of countries included in these reviews (e.g. industrialized countries in OECD reviews). In the final assumptions reviews differ in terms of "ontology" at different levels:

- Degree of inclusiveness at the country level (only industrialized countries, developed nations or all countries of the world).
- Degree of inclusiveness at the sectoral level (only formal, institutionalized science or all forms and modes of scientific and knowledge production activities).
- Degree of inclusiveness at the field level (only certain scientific fields, e.g. natural sciences and engineering, or all fields of scientific inquiry including the social sciences and humanities).

Theoretical model: Some approaches take a very explicit systems model as point of departure which focuses on input and output factors in the science system. In a range of excellent historical studies[4], Benoit Godin has shown how the original work of the OECD (which built on the Indicators capability at the NSF) was driven by an explicit interest in economic factors. More recently, national systems of innovation models have directed our attention to the more complex inter-linkages between science, technology and innovation activities as well as linkages between academy and industry. Both these approaches (input-output and NSI approaches) assume that the science or research system in the country being reviewed does in fact constitute a system in the strict sense of the world. That means that it is assumed that the science system is seen as a functionally cohesive and mutually supportive collection of "organs" or institutions that pursue a common goal (national S&T goal). It also assumes that such systems are well-articulated at all levels of the system with

[3] For an excellent and recent review and discussion of these approaches See the IDRC Report on a joint workshop held with UNESCO in 2006 entitled; *Future Directions for National Reviews of Science, Technology, and Innovation in Developing Countries*

[4] Godin, B. (2002) *Measuring output: When economics drives science and technology measurements*. Project on the Sociology of S&T Statistics. Working paper No. 14.; Godin. B. (2006) *Science and productivity: On the origins of a policy framework and its statistics*. Paper presented at the International Conference to commemorate the 40th anniversary of SPRU, Brighton, Sussex.

the required policies, actors and structures at the level of governance, funding and research performance. But as we will indicate in some cases a strong assumption about the systemic nature of science and technology is in fact not always warranted.

Other theoretical approaches (Globelics, KRIS and post-modern science systems[5]) – not necessarily in the study of research systems in developing countries though – have taken some of these issues further and have challenged us to look at other features and elements of national research systems.

Review purpose: Country reviews serve different purposes. Some – as embedded in NSI-approaches – are driven by concerns around benchmarking scientific and research performance (within a globalized competitiveness discourse). Others may be driven by concerns of capacity building (improving S&T capacity in developing nations). Others again form part of global initiatives to produce standard statistics and indicators (e.g. OECD) for purposes of international comparison. Too few, it seems, are driven by mere scholarly concerns about generating new knowledge and better understandings of these systems!

Dominant methodology: We follow standard methodological categories and distinguish between three main types: predominantly quantitative (statistical) studies, predominantly qualitative (narrative) studies and mixed-method studies. Studies that are located within global competitiveness or benchmarking paradigms are invariably more quantitative and statistical (given the presumption of standardization contained in indicators). Other studies are more anthropological and narrative in nature (e.g. some IDRC studies and the IRD-studies) and focus on the more dynamic, historical and cultural features of such systems (such as the IRD focus on scientific communities and the social inscription of science in society).

It has been argued by many scholars and debated at a number of recent conferences that current approaches to the study and measurement of research systems are not immediately and feasibly applicable to the developing and poor countries of the world[6]. There are a number of reasons that are put forward:

- The most obvious reason, of course, is that very few of these measurement and indicator systems were developed with these knowledge and research systems in mind. This is certainly the case for the OECD approach which was originally only aimed at mapping and measuring the science systems in industrialized economies.

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[5] Cf. the work by Arie Rip and Barend J.R. van der Meulen (1996) 'The Post-Modern Research System', *Science & Public Policy* 23 (5) (Dec. 1996) 343-352. Also published in Rémi Barré, Michael Gibbons, Sir John Maddox, Ben Martin and Pierre Papon (eds.), *Science in Tomorrow's Europe* (Paris: Economica International, 1997), pp. 51-67.

[6] Cf. for example; Muchie, M.; Peter Gammeltoft, Bengt-Åke Lundvall (eds.) (2003), *Putting Africa First. The Making of African Innovation Systems*, Aalborg: Aalborg University Press, 2003.

- Second, most of the existing approaches are underpinned by assumptions which are either not applicable at all or only to some degree appropriate to these systems. These assumptions relate to matters such as the following:
    - Strong assumptions about the systemic nature of science and technology arrangements in developing nations.
    - The place of universities as knowledge producers in these systems.
    - The emphasis on "innovation" and employability of the concept of a "NSI" in these systems.
    - The strong focus on standardized, quantitative indicators in order to create standardized measurement systems.
- Third, few of these approaches are inductively grounded in in-depth country case studies. Any such grounding would have shown quite quickly that many features of these systems are not taken into consideration in these approaches. These would include:
    - The role of international funding and donor agencies in not only supporting but in fact steering and shaping science in these countries.
    - The lack of a sustainable reproductive capacity in many of these systems which perpetuate their dependency on outside agencies.
    - The "fragility" of scientific and research institutions and – in fact – trends towards the de-institutionalization of science in these countries which is directly related to the lack of political and economic stability in many instances.
    - The critical role that the social sciences play in these countries especially in Mode 2 forms of knowledge production but also in maintaining consultancy science for overseas donors.

The aim of this study is not necessarily to argue for a distinctively new approach to the study of research systems in developing countries. This is an ambitious goal that would require more time and work and also outside our Brief. However, we would argue that our study identifies a number of "pointers" about how one would go about in developing such an approach. We elaborate on these pointers in the remainder of the report, but will summarize the main thrust below.

- Our approach in this study, which is also reflected in the proposed Template (Section 4), is based on an <u>inclusive</u> definition of science and technology systems. We include all forms and modes of research, all scientific fields, all levels and institutions of science (including the role of external research and funding agencies) and we also focus deliberately on the intangible and symbolic features of science: the status of science and the scientific profession in a country, the nature of scientific communities, the lasting influence of the history of science on the governance and organization of science in a country and so on.

- It follows logically from the above that we propose a comprehensive and mixed-method approach to country studies. A one-sided focus on standard quantitative measures and indicators or even standard surveys will not capture the important features of a science system (also not for policy matters). We, therefore, suggest in the final section of this report an approach that includes the use of current indicators augmented with new indicators, questionnaire surveys, bibliometrics as well as (anthropological) field-visits.
- The organizational counterpart of these methodological implications is a proposal for the establishment of Reference centres or Observatories for science and technology in developing countries. What is new in our proposal is that we see the function of such centres (of which there are already good examples) as being much more than mere repositories of statistics or surveys. They need to become true knowledge-gathering and –generating sites where information (quantitative and qualitative) on science systems in a region or country are managed. They should be sites of knowledge dissemination and utilization; of training and capacity building and through a growing network of such sites, will eventually constitute the required infrastructure that is required to enable and sustain robust and useful country studies: for scholarly and policy purposes.

1.4 PROJECT DELIVERABLES

This study produced a wealth of reports and nearly 1400 pages of text:

- Four regional compilations:
    - Africa compilation (22 countries; 447pp)
    - Arab compilation (11 countries; 238 pp)
    - Latin American compilation (14 countries; 245 pp)
    - Asia compilation (13 countries, 134pp)
- Four regional reports
    - African regional report (42pp)
    - Arab regional report (38pp)
    - Latin American regional report (26pp)
    - Asia regional report (30pp)
- A consolidated bibliography (46pp)
- A final synthesis report and template (149pp)

1.5 OUTLINE OF THIS REPORT

In addition to the Introduction in this section, the report comprises three main sections. Section 2 presents our main, high-level observations and conclusions about the nature of the research systems in the 52 countries reviewed. Section 3 reproduces – in abbreviated manner – the conclusions and findings contained in the Four Regional reports. The final section of the report, Section 4, presents the Country Template and proposed Methodology for its application which has been developed in this review. Summary Tables with the key science and technology indicators (where available) of the 52 countries are attached as Appendix 2.

SECTION 2: MAIN FINDINGS AND CONCLUSIONS

2.1 INTRODUCTION

It is not easy to summarize the findings of fifty two monographs[7], dealing with the status of S&T in countries that belong to the whole developing world. We stressed in our regional reports that there are striking differences between continents as well as important discrepancies between countries on the same continent. Moreover, no single indicator (nor a combination of them) gives a truthful and robust account of the status of science in any country (See Annex 1: Indicators). We have therefore decided not to merely present a catalogue of facts and figures – perhaps somewhat informative but dull. We preferred to draw some more bold conclusions from the analytical and qualitative data and to make tentative “assessments”.

In the next section (general view) we draw attention to three salient points:

- There is a general divide (emerging) between two main modes of research: academic research and mission oriented research. In each of them the pursuit of science is subordinated to other goals, and none of them encompasses the whole scientific field. This fact may prevent the function of research from being clearly perceived.
- According to the monographs, there is a deep crisis of trust in S&T in some countries, and not in others. This could well (eventually) lead to a “Science Gap”, with much more serious consequences than the digital gap.
- There is a formal similarity between organisational charts (arrangements?) and general statements of S&T policy. Despite these formal similarities, action plans and practical commitments differ hugely. We identify three main types of S&T policies (according to budgets, human resources, the status of science and its management in the country) in this regard.

[7] Each of them draws on a larger material of world indicators, recent monographs, and a selection of articles dealing with the status of research in each country. This is a survey; not a mere collection of a few case studies alleged to be representative.

- In the same (first) section, we also deal with the specific role of the Universities concerning research.

In the following section, we enter into a more detailed discussion of some components of the S&T dynamics. Human resources will be discussed not only from the figures' side (stock and flow), but also from the angle of the status of the profession, social integration, brain drain and scientific communities. Institutions will be assessed (whether upgrading or downgrading) as well as the new demands impacting on them. Specific attention will be devoted to autonomy and collaborations (international and inter-sectional: with the social and productive world).

We then draw some general conclusions. We will also venture some proposals (about international support and mechanisms appropriate to different contexts), as well as an indicators framework and suggestions for further case studies.

2.2 GENERAL ISSUES: MODES OF KNOWLEDGE PRODUCTION, TRUST IN SCIENCE AND SCIENCE POLICY

2.2.1 The scientific field: between academic and commissioned research.

Almost everywhere there is a divide between academic science and science pursued on assignment or as part of a specific "mission". The former is carried out in Universities, where its function is to regulate and advance the careers of the Faculty members. The latter is performed in government Institutes in fields where the State considers it has responsibilities (Health, agriculture, defence, etc.)[8] [9] [10].

The two types of establishments are run, funded and professionalised in contrasting ways. Working conditions are different (budget, careers, hierarchy). The staff have distinctively different "visions" of what valuable science is; they practise different styles of research, and they have their own supporters (in society, the government, and among donors).

But in none of the two cases is research pursued for its own sake. In the academic world, its practice is heavily subordinated to teaching. Its use is mainly to regulate the careers. Within

[8] In the same way, important firms have in-house R&D carried out subject to the markets' expectations.
[9] See the Human Resources section for a tentative breakdown.
[10] A new thing is that in countries where science is poorly funded, a number of researchers are now hired by international firms or agencies for to conduct short projects.

the Centres, the institution's mission is predominant: it entails numerous routine operations and strategic research becomes secondary to emergency tasks[11].

The two sorts of institutions are two ways of managing scientific production (discovery). Both have credibility and their establishment are founded in strong historical and practical reasons. But their frequent corporate disputes (between full time researchers and academics, engineers and holders of university degrees, "relevance" and "excellence") hide a basic question: Does research now have any legitimacy in developing countries? And if so, which one of these two modes of research?

Should these countries maintain their own effort? Or would it be better if they simply "help" themselves from the available shelves of the world supermarket of technologies? Is research beyond their reach or what can their strategy be? What expectations may they have, what goals can they pursue, within which sort of organisation?

These are real policy questions. How to become efficient and relevant[12], within anticipating niches? Is sufficient human potential available for them? How to identify encourage and pool the appropriate actors in critical masses? What constitutes a fair allocation to basic research and how does one ensure its link to implementation? Which web of international collaborations should they spin while retaining sufficient degrees of autonomy?

The answers to these questions are neither self-evident nor simplistic. Some countries leave it to international cooperation, or to multinational firms[13]. Others have their own programmes, which do not target only one sort of institution[14].

In all cases the function of research, in academy as well as in Institutes, cannot remain the same as it was during the time of "national science": before the era of globalisation and where scientific capacities increasingly became linked to market and technological innovation. It is advisable for each country to canvass the opinion of external (foreign) experts who are well versed in science frontiers and technological stakes and invite them to assess the best laboratories in order to make proposals on main assets of the country[15].

2.2.2 Trust in Science.

Since the mid 1980s research has experienced a big crisis in a number of developing countries. This is a threefold crisis:

[11] Some Institutes elaborate on a « research plan » to palliate this flaw (INRH, Morocco).
[12] In basic research efficiency means dealing with frontier topics and relevance making an important impact. In applied research efficiency means finalizing new products or processes and relevance rallying firms to make use of them.
[13] E.g. some Gulf countries try to attract and territorialize both important MNF and prestigious world campuses.
[14] E.g. calls for tenders, rallying technological projects, "clusters" of different institutions dedicated to a special field and located in a particular area, etc
[15] E.g. See the Moroccan evaluation of its national research system (in *Le Maroc scientifique*, op. cit.). Laboratories from University, Centres, Engineering Schools, and the main enterprises were visited.

- Financial crisis: Acting out of their own impulse (Algeria…) or under the pressure of debt and structural adjustment many governments dramatically downsized their contribution to research[16]. Among them are most of the poorest ones, but also many oil or "comprador" countries (Nigeria…) and some of those which had previously banked on great technological projects (Philippines, Indonesia…). GERD as a % of GDP no longer exceeds 0,2 % and research expenditure pays for the salaries of researchers (but not for operating projects).
- Professional crisis: the profession is devalued. Salaries are frozen and were even diminished by the State or by incredible inflation. Grants for improving the profession from abroad have diminished. Civil servants are often considered as unproductive, and even accused of being parasites (Tanzania). Recruitment is suspended. Brain drain wreaks havoc. "Relief troops" are not there. The gap is filled with poorly paid temporary staff. The profession has become proletarian.
- Institutional crisis: governing bodies are no longer called for advice or meetings. They lose their hold on the performers. With poor funding from the State (often their only operating resource) a number of establishments have shown themselves unable to re-think their role, put forward a label, mobilize clients, sell their skills and keep their scientists. A number of those emigrate or change their trade, others deskill by practising pot-boiler activities; some of them hire their scientific capacity out or deliver consultancy to foreign research projects. Research is de institutionalized. It is practised outside the boundaries and schedule of the establishments, by mutual agreement between a researcher and his sponsors: a market of the scientific work is incipient[17].

These crises are rooted in another deeper one: a crisis of peoples' and governments' trust in science and its role. One should not forget that half a century ago (from the 1950s up to the mid 80s) major efforts of the newly independent States, generously relieved by international aid, were invested to create and equip institutes and universities and to train high quality specialists. In this era of "national science", there was confidence that Enlightenment would bring modernization, that education would favour poor peoples' social mobility, and that development solutions would spontaneously ensue from research. Globalization and the triumph of economic liberalism have changed the deal. Progress is no longer expected from the discoveries of science but from enterprises' innovations. Welfare is no longer awaited from the State's intervention but from the free play of the market. The old pact of science with the society is broken and a new one has to be devised. The reasons to support it must be renegotiated and renewed. They can no longer just stick to

[16] Whether done in Centres or in Universities. By the same time – after the end of the Cold War - the international aid dropped. See Busch: *Who still needs the Third World?*
[17] This situation prevails in a number of "small" scientific countries, not included in our sample. It can be observed in a majority of African countries (South of the Sahara), in a number of Andean countries and in some Asian ones (Nepal, Bangladesh, Sri Lanka, Indonesia, etc.).

the old arguments of improving the quality of tertiary training, or of providing the country with the whole of new technologies it needs[18]. It is a matter of putting forward new convincing reasons to pursue research in the country, and prove that its implementation is relevant and beneficial to the nation.

2.2.3 Policies

Except in the Gulf and the Caribbean there are now very few countries which are not equipped with national authorities in charge of research, general statements of S&T policy and "visions" outlining the tasks to accomplish. Oddly (maybe under international pressure), there is a formal similarity between their organisational arrangements and declarations of intent. Despite these formal similarities, action plans and practical commitments are very different. We describe three main types of S&T policies (according to budgets, human resources, the status of science and the goals allotted to research).

1) A small number of countries ("emerging" or candidates for emergence: ten or so in our sample[19]) bank resolutely on science as ***a tool for innovation***. Support of the State has been steady and long lasting. Budgets are important[20]. Incentives target all sorts of actors: the researchers themselves, who may earn significant bonuses if they pass through an assessment (Latin America: Mexico, Venezuela, Uruguay…); laboratories, which get long term and better funding if they are appraised positively (Tunisia); successful establishments which raise more funds through their quality label (South Africa); enterprises which are encouraged to invest in R&D through a number of measures (tax incentives, grant of facilities, technological services: Thailand). Other measures aim at bringing closer research and firms in the same vicinity (Singapore's technopoles, Malaysian "clusters", Chilean and Mexican regionalisation of R&D). All these measures are periodically assessed and revised. They try to establish, if not "systems", at least *innovation biotopes*[21]. They are seeking international cooperation (often in specific niches, and to participate in big technological programmes).

2) On the opposite side, a great number of countries consider science as ***a "luxury***", distant from their needs or out of their reach. They accept foreign funding but they do not support projects themselves. Their policy is one of *"laissez-faire".* This did not prevent the

[18] Multinational firms, clients and suppliers of the national enterprises, etc are among the possible new sources of technological learning and progress.
[19] Singapore, Mexico, Malaysia, Thailand, Argentina, Chile, Tunisia (maybe Venezuela). The same policy is valid (beyond our sample) for Brazil, India, China, South Korea, and South Africa.
[20] GERD is over 0,4 % of GDP (and more often over 0,7 %, with a significant contribution of the State for the private sector is not always sharing the expenditures (e.g. Tunisia).
[21] Cf *Science, Technology & Society*, special issues Innovation : Asia 10 (1) 2005 ; Latin America 11 (1) 2007

establishment of national authorities for R&D (controlling cooperation), and some expenditure by the State (which pays for the salaries of researchers and academics)[22].

A number of these countries struggle in the throes of poverty and war. Others are poor and in search of emergency solutions. But there are many other cases: “compradore” countries or those rich with oil royalties which do not need research for economic reasons; it may just appear to them as a decoration. The socio cognitive bloc in the corridors of power plays its role. Regimes based on tribute, rent, patronage and clientelism, proprietary interests or military dictatorship may have interests and values very divergent from those of science. They in fact are anti intellectualist. Finally, several countries are committed to radical free market policies. They consider they need technology (not science) and technology is a concern for the enterprises: such enterprises can get by through their networks on the global market.

The little science that remains relies on key figures and small circles of specialists. The responsibility for international **cooperation** is high - in order to support these scientists, ensure some degree of viability (or more relief), offer methods that will make efforts sustainable: networks of laboratories, sanctuarisation of research in some universities or in regional excellence Centres, labelling skills and promoting innovation programmes including research[23]… A number of formulas have been tried for this ***institution building*** that deserve being assessed.

There is another major issue: how to get the authorities to take an interest in science? Or should it be put in the hands of private initiatives (prestigious universities, international firms established abroad, enlightened sponsors[24])? Should support address only a minimum of basic science? Or should it encompass technological programmes combining local and global actors, private and public (as the famous agreement between the government of Costa Rica and Merck’s pharmaceutical industry to protect and value the bio diversity of the country)?

3) A third type of policies concerns “***intermediary***” countries. They are fifteen or so in our sample[25]. They have not yet clearly identified a function for research. Support from the State has ups and downs. But institutions are strong, some establishments are robust and

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[22] GERD is rarely under 0,2 % of the GDP. Between 0,2% and 0,6 % one can find countries which despise research or hold it in high esteem. Other indicators, and narratives are necessary to describe the status of science.

[23] Some of these may well be grass roots projects, as the US AID programme for poor peasants in East Africa developing the cultivation of tropical nuts with high value added as starters in Europe. The big point was to ensure them a market, and trade channels before even beginning with the agriculture project.

[24] All of them play an important role in the Near and Middle East. See the monographs.

[25] Venezuela, Colombia, Uruguay, Costa Rica, maybe Panama; Viet Nam (may be Indonesia); Morocco, Algeria, Egypt, Jordan and Lebanon; Kenya, Cameroon, Senegal, Burkina, Ghana, Uganda (and with ups and downs: Nigeria, Tanzania and possibly Zimbabwe).

professionalisation of researchers is firmly rooted. They can take over temporarily when the State withdraws.

To build a strategy is most difficult in such countries. They often have small or medium sized markets (not large internal ones) and they are new comers in well defended niches. They have established long ago a tertiary education system with good standards (which makes them vulnerable to brain drain). They must value their present resources, and *imagine their future along new paths* and advantages to build. Scientists may help a lot, if they are able to open up realistic and anticipating niches (for which excellent capacities do exist in the country, as well as an international technological stake and identifiable users of the results).

There are specific responsibilities for *cooperation* here: the first one is to help identify original topics and give credibility to the local capacities; the second one is to support programmes in these innovative niches.

It must be stressed that current indicators are misleading as guides to categorize all countries. Some countries do not seem disposed to an interest in science on account of their size (small), their wealth (low), their type of resources (primary, exported raw), their economic structure (no industry); but they are more impressive than at first glance if one reads the monographs dealing with them. This is the case for Burkina[26], which is a poor country, and which has been supporting science for a long time. Its institutions are strong and highly regarded. On the other hand, Philippines and Indonesia (the last one for a while had an ambitious technological policy) seem better equipped but they allocate an inferior status to science.

There are lessons to be learnt from these inconsistencies. The first one is there is no fatality. There is room for R&D policies. The strategy is of course all the more tricky as the efforts are overdue, the budgets poor and the capacities limited. International cooperation has great responsibilities.

The second lesson is that indicators should be validated through monographs, giving a flavour of the status of science; and if possible complemented by scientific external assessments, aiming at identifying original and realistic useful niches for R&D.

2.2.4 The Role of Universities.

Does the University have a specific and distinctive role in Research? What can the role of research be for Universities? It is advisable here to go beyond conventional views.

[26] And also Cuba or Uruguay ; Jordan and Lebanon ; Cameroon, Senegal and Mali, etc.

*1) The function of Universities **for research**.*

a) The university is best placed for *training* tasks. Some of these are of interest for research:

- It is necessary to renew continually the "reservoir" of future researchers and teachers.
- but training through research should not target only the reproduction of the profession. It has specific virtues that could endow highly qualified staff in the productive sector with constant curiosity about recent discoveries, rigour and creativity.
- This entails that research be linked in Universities to national priorities and practical stakes; and that the curriculum makes room for experimentation and students' initiative. Part of the scholarships could be reserved for joint doctorates with enterprises, and part of the academic research run under contract with clients.
- University can invest into continuing education and in-house training for employees in "strategic sectors" (and create dedicated Institutes, as in Singapore about biology and medical biotechnologies). This (and a part of services provided to industry) is a predisposing and enabling factor for the development of R&D in firms and the establishment of sustainable links with them.

b) The university is best placed to ***sanctuarise*** research amid adverse fortune (especially a fair share of basic research):

- because it harbours the greatest numbers of researchers with the highest diplomas;
- because its organisation is auspicious. Departments are built up on disciplines; and the assessment of staff take research into account;
- researchers have more freedom here (schedule, choice of topics) than they have in Agencies and state institutes (where they may at any time be called back to routine and emergency tasks). They have incorporated the scientist's ethos; they are more inclined to publishing, and turned towards the international community, its associations, organs and events;
- nevertheless, research at University will be efficient only if it is not regarded as an individual task, if critical masses are forged, and if topics dealt with are "well positioned" (taking into account the advancement of world science, global technological stakes, and a reasonable link to social actors and national priorities).

c) University may take on a *watch* function, and the *liaison* with international sources of knowledge.

- o For this liaison to be real it should be applied. It is the responsibility of Universities to cultivate their relations with users, in order to be heard and followed regarding innovations.

- More generally, Universities should assume the mission to *raise the standard* of technical knowledge and the way of stating and solving problems by considering the latest world progress on their matter[27].

d) In the national system, the role of research in Universities may then be that of "*strategic research*", drawing from frontier knowledge to rephrase immediate and impending problems, imagine and test novel solutions to them.

- Academics in the developing world are generally in a difficult position to compete with large well equipped and connected laboratories of the metropoles of science. But they may build good niches and approach the frontiers. Contrary to their reputation they are also most often turned towards (would-be) applied research.
- Their main handicaps are insufficient access to first hand up-to-date publications, robust equipment and links with the productive sectors.
- If these disadvantages are overcome, and cooperative projects are run with the productive sector (keeping to its constraints of deadlines and market) University can well become a source of real innovations.

To sum it up, the raison d'être of University research exceeds much of its traditional justification (enhance the quality of training and ensure the reproduction of the academy). These are two important goals; but the need for academic research is beyond them. University is best positioned to link with the world scientific community, and with the advancement of knowledge. It is most capable of doing whatever basic research is necessary, but also to mobilize its results and translate them into ideas of "strategic" implementations.

2) The function of research ***for Universities****.*

a) We already mentioned that research was indeed an asset for the *quality of training*:

- not only the training of academics and researchers to-be
- but the training of all sorts of highly qualified technicians, whose knowledge will remain relevant on a long term basis. A complementary task for Universities is the continuing education of staff in the productive sectors.

b) But research is also part of the *professional ambition* of academics:

- It is their way to keep themselves up to date, to remain informed of the advancement of world science and gain a sense of market and technological stakes.
- Equipped in this way they may aim at competition with other colleagues and laboratories, local and foreign. They may build scientific comparative advantages, choose original topics, select opportune co operations and carry out autonomous work.

[27] Experience shows that technicians in charge have little time to keep their knowledge up to date. They have to rely on old skills and certainties. See e.g. "*Le Maroc scientifique*", op. cit. about water management.

- They can enter into contractual collaborations with local users who will take them seriously.

c) Research also gives institutional *credibility to the establishments*.

- o Many Universities deliver good teaching. Research is a label which makes a notable difference (See the “Shangaï list of the top world universities). It guarantees (supposedly) that the best talents are there. It attracts students and helps raise funds and contracts[28].
- o Research is also a way to enhance the social inscription of the University in its region, through “clusters” of collaboration with local users.
- o Research may attract to the establishment a long lasting national reputation of quality, in branches which become its speciality (See “water” for Kenitra University, etc).

2.3 COMPONENTS OF SCIENCE AND TECHNOLOGY

2.3.1 Human resources

The question of Human resources has to be considered not only from the perspective of figures and indicators (stock and flow), but also from the angle of the profession (ethos and means), availability and adequacy to modern challenges.

1) Numbers

The country reviews show that the theoretical number of scientists in the developing world is not small. Especially, the number of academics (all supposed to do research) is important in most countries: except for Africa (east and part of west) and a few Asian countries (Pakistan, Bengla Desh, Nepal) they are all on a path of mass tertiary education.

Of course, the proportion of researchers to the total population (and even to the labour force) remains below the average of developed countries. But the main problem does not seem to be a radical shortage of capacities. It is rather a question of quality (modern specialties and up to date knowledge) and availability (means and readiness for intensive research)[29].

The main point is that only a small part of this potential is available for research. Some monographs attempted a detailed account of researchers “Full Time Equivalent”[30]. They

[28] See examples in the section “Good practices” (Morocco, Tanzania etc.).

[29] Researchers in Latin America and in some Asian countries have often lower degrees than in other parts of the world. This reflects the fact that doctoral studies were developed late on these continents. But it is not necessarily a problem, as far as a sufficient number fulfilled Ph D abroad or had retraining courses, and if they work in a body within laboratories.

[30] Especially in countries which select them through “national systems of researchers”: Mexico, Venezuela and others in Latin America; or through their affiliation to accredited laboratories: Tunisia, Algeria… See also precise

come to ratios of 1 out of 10 of the supposed potential (See the Indicators section in Regional reports). Bibliometric data confirm that in small and medium size countries, the strengths of the best establishments often depend on small teams of 5 to 10 active researchers (backed up by the same number of occasional producers)[31]. The reasons are that other missions are considered more important in Universities or in commissioned research centres (see Section 2 above); and above all that the profession has been ruined in several countries: researchers have then subsequently turned to practise a second or third activity to earn their living and they bypass research, which is poorly rewarded.

2) Critical masses

The outcome is that it is difficult to bring together critical masses in priority areas; and even to maintain the strongest points – which depend on a few key figures, small circles of specialists, and remain fragile. Some consequences are:

- it is necessary to find *new incentives* for the researchers;
- it is necessary to consolidate the building blocks of research – namely sizeable *laboratories* equipped and well funded, submitting to periodical assessments.

It is advisable that they be linked as soon as possible to an international network. The last concern is related to the first one (as good working conditions is one of the main needs and wishes of the researchers)[32].

3) The Profession

Their life and working conditions affect the productivity of the researchers, as well as their choice of topics and the relevance of their undertakings.

Remuneration and career perspectives are part of it. We have reported (and we shall elaborate on this in the “regional” section) that until the 1980s they were attractive. But in many parts of the developing world the situation has greatly deteriorated. Exceptions are the Arab countries and the emerging ones[33]. Almost everywhere else the salaries have become insufficient to provide a decent life to a family. Recruitments are frozen, or they are made from a precarious base. Progress in the career is modest and pensions are minimal.

There are two main consequences: the first refers to the brain drain. The second relates to the quality of human resources.

data for Lebanon, Jordan, Morocco, etc. in the monographs and in the Indicators section of regional reports for Latin America and Arab countries.

[31] See for example the case study of Jordan, in *ESTIME* project : *Bibliometric analysis*.

[32] This does not exclude that other personal incentives appear necessary. In Mexico, Venezuela etc, productive researchers are awarded significant bonuses. In Tunisia, the managers of laboratories may have reductions of their teaching load.

[33] But Algeria and Egypt have ill treated their professionals – especially academics and researchers. And catching up is a rather new policy even in emerging countries (or candidate ones: Argentina, Chile, Malaysia…)

4) Brain drain

Numerous students who left to improve their positions abroad do not come back home. And many academics or researchers emigrated since the 1990s. Figures are difficult to find (though descriptors and narratives are plentiful). But we discovered some accurate ones (See regional section). Clearly brain drain has become a massive and structural problem (the principal one) in countries like Egypt or Algeria, and generally in Latin America, in Africa and in a number of Asian zones. As regards the Caribbean and Andean countries, there are more (or as many) highly skilled persons working in R&D in USA than in their home country. The same is true in a number of well documented African countries (all the more their tertiary education is good). Exodus is important in Argentina, Colombia, Egypt and the Maghreb countries.

This is a serious concern (and we are far from any reverse brain drain). No “good practises” can be quoted that proved to be radically efficient. The only way to slow down the outflow is a sizeable revaluation of the profession, together with a proper structuring of research (good conditions of work in assessed laboratories, merit pay and promotions, as outlined by Mexico or Tunisia).

5) (De) skilling.

If they do not change their trade or leave the country many academics have no choice but to work on the side: overtime hours, consulting or any sorts of trade bearing no relation to their skills or research. They have no time to “breathe” and refresh their knowledge. The situation is all the worse as there are very few opportunities for sabbaticals, internships and training periods abroad, and participation in large multinational programmes.

There are too consequences for the “substitute workers”. Students in the (often new) doctoral programmes are not always supervised and mentored by up to date teachers; and they have little opportunity to participate in international Conferences, or to be exposed to world science and be challenged by its standards.

6) Working conditions

Finally, and this is well known, the tools for doing normal duties are lacking. This is especially true at University. Academic laboratories are regarded as sub-standard by enterprises because their equipment is too old[34]. Because of a lack of maintenance and consumables, it is also often out of service. The lack of first hand up-to-date documentation, and of face to face interaction with the leading world researchers in their own laboratories maybe an even more serious handicap: it hampers autonomy and imagination.

[34] It may be good for teaching, but not for research and even less for delivering services.

7) Ethos, Norms and Values.

For a number of researchers, there was a deep change in their method of production. They manage to keep up to date with developments in their field, and to earn a living from research by hiring themselves (through contracts and projects) on a world market for scientific labour. The trade is practised in the framework of commisions and temporary work (not own intuition and career making), within world consortiums and networks. Demand drives the agenda, and the market distributes means and rewards (not the academy). These changes generate splits between different professional ethoses. Some researchers remain attached to the values of “national sciences”, including the autonomy of the learned institutions, the assessment by peers, the valuation of excellence and individual work, funding by the State and the pursuit of national interests. Others advocate commissioned research, susceptible to economic and social demand, open to the market, with world horizons and transnational norms. Different archetypal figures of success confront each other: the Academic, the Consultant, not counting the political Activist (a frequent destiny for intellectuals).

8) Challenges and solutions.

Whatever these internal debates, there is a clear need for the maintenance of the capacities, and of keeping to the world standards.

There may be some problems with replacements, upgrading the existing skills or introducing some new disciplines. Nevertheless, the main question is probably not “capacity building”, but rather preventing established capacities to disappear. Co- operations have their role to play, as well as a support from local actors.

Among many “good practices” (described in the monographs) we’d like to highlight two points:

- There are “living treasures” in each country: dedicated scientists who persist in doing research and whose output makes an impact. It is advisable to identify and support them as a priority (instead of “putting the past behind”: for experience proves they are the most robust component of the “science system”).
- The best way to build sustainable capacities is probably to immerse them immediately in well built institutions: viable laboratories, excellence centres and international networks. This means that institution building is a precondition to capacity building.

2.3.2 Institutions.

We already touched on governing bodies (Section 2. Policies). We deal here rather with the performers. How is science institutionalised at their level? What are the new demands impacting on these establishments (in a globalising world: new management, new functions of research, new goals and new corporate strategies) ?

1) Institutions versus market?

A first remark is that in a number of small scientific countries, research is on a path of de institutionalisation. As States disengaged from funding the running costs of projects, external demands prevail: private contracts, after or not tenders were invited, are offered to individuals or teams, operating in an informal way out of campus[35]. Atomization and the extra-territorialisation of research are the expression of a wrecked profession, and of the decay of numerous establishments (which find it hard to adapt their vision and their management). They have consequences for the researchers' ethos, the hierarchy of disciplines, the choice of research topics and of course the volume of production and publications[36].

Nevertheless, institutions are necessary even to the markets of scientific labour. They maintain a "pool" of researchers supposed to be up to date and available. They ensure their reproduction and their maintenance during in-between times (between two projects). From a national point of view, they have a critical role (especially when there is no public policy) to envision and build long-term strategies and gather the necessary partners (for co operation and funding). Much of this relies on the management capacities, the charisma and the vision of their rulers.

[35] This is notably the case in human & social sciences, where international consultancy becomes a norm of the production. E.g; in Ibadan (a prestigious Nigerian University) "publications and conferences tend to be neglected, the socio economic status of an expert grows in a quick and sometimes spectacular way, turning even upside down the social hierarchy within the campus which was supposed to reflect academic ranks and degrees"

[36] Production does not disappear (but it is reduced). Above all it appears in most informal forms, lending itself badly to publication (reports, papers read in conferences, grey literature…)

2) The changing function of establishments.

Let us distinguish two types of establishments : Universities and Research Centres. The changing context (economic globalization, new modes of scientific production) impact on them differently.

a) Universities are facing two challenges:

- they must compete for funding and acquire a “research label” in the opinion of sponsors.
- they have to value (and even protect) the whole spectrum of research (from basic to applied) and draw up adequate criteria for their assessment.

The pursuit of a research label demands ambition and rigor from the researchers and often deep changes from the establishment. They entail:

- The organization of the research function (persons in charge, facilitating services)
- Drawing up a strategic plan for Research
- Budgeting the activity (through a deduction from the receipts of continuing education, services to customers, research contracts, Department budgets…)
- Setting up incentives (bonuses, profit sharing in contracts, reductions in teaching load…) and redistributing the tasks between members of each Department (some teaching more, others doing research, some taking leaves to refresh their knowledge or initiate to a new field)
- Establishments have to cultivate links with customers, enter with them into contracts, de bureaucratize their management, modify programmes and keep aware of the neighbouring needs.
- They have to think about scientific relevance and socio economic efficiency, keep up to date and try to build comparative advantages.

Few Universities will become “research intensive” in this way. A number of other establishments will simply commit to some strong points, which may be useful in their region. And the great number will probably do no more research than they do by now: almost none reflected in international indexes and databases[37], even though careers are supposed to be regulated by research achievements[38].

[37] Bibliometric data show that in each country the bulk of production (at least 50 %) relies heavily on 1 or 2 establishments. Between 1991 and 1999, only 100 African establishments produced on average more than 15 publications per year (PASCAL Database, next table):

	ZAF	EGY	NGA	KEN	TUN	MAR	DZA	ZWE	SDN	TZN	CMR	CIV	SEN	GHA	ETH
Univ	14	15	11	2	4	5	4	1	1	3	1	1	1	2	1
Centres	17	4		3	3	3						2			

Among Centres : 6 international ones: ILCRA, ORSTOM, Pasteur, ILRAD, ICIPE, IITA

[38] This is an excellent rule. But assessment and the use of these researches are strictly in-house. And the new private Universities generally don’t care any longer about research.

Nevertheless it is important that “Research Universities” do exist, and behave as the guardians of norms and standards, a bastion against quackery, and the protectors of a relative autonomy of the scientific life vis-à-vis other social interests.

b) Centres are facing more serious dilemmas. Some of them are purely dedicated to Research (basic and applied)[39]. The challenges are the same for them as for Universities: adapt to new modes of productions and raise ambitions (international quality and anticipating relevance). They may be equipped to face them for it is part of their regular brief.

But the majority of Centres is “mission oriented” in another way. A number of them were set up to be the providers of new technology to national (government-owned) enterprises. They were sometimes entrusted with sensitive public services requiring accuracy and reliability (producing vaccines, or selected seeds…). By now, a private sector has emerged that can do the last job; and numerous sources of technology are at the disposal of firms (which carry out technological learning through their clients, their suppliers, or through joint ventures with foreign enterprises).

The mission of such Centres can be questioned. What can their strategy be?
- turn into “Technical Centres”, providing services to local community enterprises (e.g. certification, incremental innovations…)
- position themselves as the arm of the government in “social programmes”, meeting insolvent needs or offering non market services
- offer sophisticated technical services to international firms (whether abroad or when they establish in the country): this entails the capacity to confront world competition

c) Consequences

Achieving a research label is a good strategy for Universities as well as for the Centres. But it entails a number of changes in their ethos and their management.

- It calls for a “re institutionalisation”, or institution building, in which co operations have a role to play (training for management, finding new partners, integration into networks of labs and innovative firms, etc)
- The first step is probably the strengthening (and sometimes the mere setting up) of adequate building blocks, namely: laboratories, of sufficient size and consistency.
- Strict *assessment* with clear criteria, taking into account the various outputs of research becomes a crucial need.

[39] E.g. the National Centre for Research in Egypt, etc. Other cases are Agencies in charge of national (strategic) missions, such as nuclear research, maintaining big scientific facilities, surveying territorial waters, etc. They have at least to take globalisation into account because of the possible poaching of their best staff by R&D delocalized private and international Centres.

(Note: See Annexure 1 for data on the output of the top universities in Africa)

2.3.3 Co operations.

Co operations are an important component of the S&T system and even of the S&T policies in the developing world. They perform multiple functions and contribute to the status of science.

1) Figures

The proportion of articles written in co authorship between scientists of a country and foreigners is an interesting indicator of co-operation.

- There are few co authorships between one country and its immediate neighbours in Africa, Asia and the Middle East. There are a few more in Latin America.
- Most of the international co authorships (over 90 %) occur with scientists from the metropoles of science (Europe, USA, Japan).
- Large emergent countries have a high proportion of articles without international partnership: Brazil (65 %), India (80 %), China (75 %), Asian NICs (75 %).
- On the contrary, intermediary and “small” scientific countries (our sample) have a high level of co operations: *40 % in Latin America and the Middle East, 50 % in Africa and Asia, and 60 % in North Africa*[40]*.*

2) Goals

Co operations are pursued with different goals:

- Countries which are “candidates for emergence” are in search of support in the areas of specialisation they target, and are interested in participation with big technological programmes[41].
- “Intermediary” countries have not yet specifed their target areas. They are in search of help to make a decision and they try a number of sub fields[42].
- “Small scientific” countries strive to safeguard the circles of specialists they may have. This is also the strategy of under developed disciplines or emerging fields in all sorts of countries[43].

3) Forms and Functions

Co operations are useful also in the developed world. They consist of exchange of material to examine (like strains in biology), the learning of methods and skills, the choice of

[40] Data: *OST: Paris*, 2004. There are a few exceptions: Egypt (25 %), Nigeria (30 %) but they are often ascribed by observers to “in-breeding” more than to self-sufficiency.

[41] Examples are Thailand, where co authorship exceeds 60 % in biology (basic and applied to agro-sciences and ecology: specialisation); or Chile where co authorship is maximum in Astro & Geo sciences = participation to international programmes.

[42] See Jordan (pharmacology ; energy engineering ; computer sciences…).

[43] See physics and mathematics in Chile, Fundamental biology and bio ecology in Morocco, etc.

equipment, and internships in foreign laboratories[44]. Participating in joint projects and consortiums (interdisciplinary and multi national, as in big European programmes or Arctic and oceanographic programmes) gives access to frontier science and world technological stakes, encourages the enhancement of skills and standards and gives rise to self-evaluation.

For developing countries, co operations have yet other functions:

- They consolidate the activity by creating networks between establishments and researchers.
- They may contribute to capacity building (scholarships targeting missing specialities and know how; internships and sabbaticals for updating or converting skills)
- They may contribute to appropriate institution building (training research managers, bringing establishments up to standard, strengthening the labs and involving them in networks…).
- They may help linking R&D to innovation, by supporting ad hoc programmes[45].
- They belong to the very strategy of countries eager to climb up to the top of the range, which negotiate and build them according to their priorities.
- They may even be the only source of operating funds for capacities that would be otherwise lost[46]. Through donation in equipments, free access to training and lab analyses, or offering connections and documentation they maintain the core activity of some scientists.

Co operations may take place between teams and researchers of different status (public, private, Universities, Centres). They may operate in the framework of formal agreements between establishments or between two States, or in an informal way, within temporary or long lasting consortiums. They may be offered by the world community itself (world associations; “big science” equipments: nuclear, astro or oceano…), by establishments or laboratories from the metropoles of science, by bi or multilateral co operation schemes, by Foundations (Ford, Rockefeller…), by international organizations (UNDP, WB, UNESCO) or by small and big NGOs (WWF…). They may take the numerous forms of programmes, projects, personal invitations, through cooptation or calls for tenders; and they may pertain to basic science or (more often) to studies and adaptive science.

The amount of funding coming from the variety of international sources is very difficult to establish: it is often channelled through mutual agreements and contracts. But the impact of such support in “small scientific” countries is noticeable and instantaneous (whether incoming or withdrawing). Examples are Ghana or Uganda, which after years of dereliction

[44] This is true in the metropoles of science too
[45] Incubators, technological and liaison services in Universities, twinning of labs & enterprises of 2 regions…
[46] In countries which gave up supporting science, except for the meagre salaries of the researchers.

showed a production bounce after becoming the target of US-AID and UK scientific co operations in the 2000s[47].

3) Opportunities and Risks

Participating in short-term foreign projects (or parts of research projects) is often the only way for some teams or researchers to survive. The risk is that being hired in this fashion they lose control of the agenda, and even get deskilled bit by bit, restating a doxa (in social sciences) or lowered to an engineering role in “problem solving” initiatives.

On the contrary some long-term cooperation programmes help laboratories to get more visible, elaborate development plans and raise their ambition. In such a case there is still a risk of dependency. Achieving autonomy is a complex *intellectual* question. It includes choosing a topic where being in the field entails a comparative advantage (a shortcut to discoveries)[48]. At least the topic must not entail an unequal division of work. This again supposes that the team in the South is well documented and aware of the advances of science and technology through the world.

In all cases there is a need to select co operations that will be reliable and long standing. And in all cases, co operations have a real responsibility in maintaining science in the developing world.

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[47] In another field: the Ford Foundation must be acknowledged to have rescued the social sciences in Latin America during the 1970s and in East Africa during the 1990s. It contributes (with others) to “re professionalize” these disciplines in the Near East, by supporting a number of new private centres skilled in the art of field research, action research and public debate.

[48] Good examples are work about endemic plants (with a view to make drugs) or about specific genetic diseases (when endogamy makes them more frequent).

SECTION 3: SUMMARIES OF THE REGIONAL REPORTS[49]

3.1 AFRICA REPORT

Introduction

Our review of sub-Saharan African countries produced country reports for 17[50] countries: Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mali, Namibia, Rwanda, Senegal, Tanzania, Uganda, Zambia and Zimbabwe[51]

Although these countries were selected because they met the criteria (relatively poor developing countries and not well-researched) of this study, there are still significant differences in their science and technology systems. These differences are due to many factors: socio-political histories, geography, political and economic (in)stability, different legacies of colonial science influence and subsequent science institutionalization development and so on (Cf. Appendix A: Indicator Tables).

One example of the differences between the seventeen countries is illustrated by differences in scientific output as measured by articles published in the ISI-indexes. In terms of this measure, one would distinguish between three clusters of countries: those countries (Kenya) that produced more than 2000 publications between 2001 and 2004 (Tijssen, 2006); another cluster of countries (Cameroon, Tanzania, Ethiopia, Zimbabwe, Uganda, Ghana and Senegal) who produced at least 500 publications and then the remaining countries who produced less than 500 or – stated differently- less than 100 articles on average per year. The African picture of scientific production is no less skewed than any other region of the world!

The main findings of our country studies in sub-Saharan Africa are presented according to the following five themes:

A. Recent trends in governance and policy development in S&T
B. The institutional landscape: institution-building or de-institutionalization?
C. Current state of human and infrastructural resources

[49] The four "Summaries" presented in this Section are in fact more comprehensive and detailed than "standard" summaries. We decided to go this route for two reasons; (1) we do not necessarily assume that all readers would take the time to read through the full Regional reports that are under separate cover; and (2) the Main findings presented in Section 2 of this report build of many of the observations and conclusions presented in the Regional Reports. It is, therefore, important for us to be able to present to the reader the background and more detailed reasoning to our Main findings.

[50] It was, in the final analysis, not possible to compile reports for Benin, the Gambia and Nigeria.

[51] This regional report is based on the individual country reviews contained in the Africa compilation as well as some additional references. The authorship(s) of the individual countries in the Africa compilation are clearly identified and acknowledged in the compiled report. In summary, therefore, I only list here the individual authors of the country reviews: Nelius Boshoff, Simone Esau-Bailey, Jacques Gaillard, Hocine Khelfaoui, Mziwandile Madikizela, Johann Mouton, Nya Ngatchou, Mluleki Nkwelo, Nomahlubi Shezi & Frank Teng-Zeng, Florence Verlhac, Roland Waast and Erin Zink. I also wish to acknowledge very useful comments and corrections by Roland Waast and Jacques Gaillard to an earlier version of this report.

D. Information scientific structures and scientific communities
E. Knowledge production and output

A. Recent trends in governance and policy development of S&T

Our meta-review of seventeen countries would suggest that it is possible to discern at least three very different trajectories as far as science policy development is concerned within the African countries studied.

- The first trajectory refers to those countries which have gone through two waves of science policy development: during the first wave (not too long after acquiring independence) a first S&T policy was developed but during the subsequent years was allowed to become dormant and ineffectual. A second wave of policy revision was instigated more recently (1990's and after) in order to recapture the essence of the science policy goals. However, not all countries managed to revise their policies effectively with the result that there is now a very evident policy vacuum in some countries (e.g. Kenya). This category of countries includes Ghana, Kenya and Senegal.
- The second category consist of countries that established their first S&T policy documents in the 1990's and even more recently (after 2000): The majority of countries included in our review fall into this category.
- A third – and small category of countries in sub-Saharan – still do not have a S&T policy, e.g. Mali and Swaziland (not covered in this survey).

Two interesting trends emerge from a cursory inspection of the existing science policy documents:

- The tendency to imitate – rather slavishly and uncritically – science, technology and innovation policy approaches and paradigms from elsewhere. Some examples; This is evident in the Ethiopian S&T policy document where there are uncritical and fairly inappropriate comparisons with the science systems in South Korea and Malaysia. It is also evident in many African documents that aim to emulate and adopt the concept of "national systems of innovation" (NSI) to their own science systems. Such an emulation is highly inappropriate given the early developmental state of local science systems. A derivative of this tendency has recently manifested itself in Southern Africa where some Southern African countries (most notably Lesotho, Namibia and Botswana) are currently emulating the science and technology policies of the South African government. This is perhaps not surprising given that experts from South Africa have been called in to assist in the development of these policies and plans (e.g. Botswana) and because of the closer relations amongst these countries.

- A second pattern that has emerged is found at the substantive level where one finds a large degree of similarity in the content and emphasis in these documents. Again, this should not be that surprising as most of these science policy documents have originated in a globalizing world where national boundaries and national goals are increasingly subsumed under inter-national interests. Most of the science policy documents crafted over the past decade or so therefore have very similar contents and identified priorities, e.g. focus on science and technology for development and economic growth, the adoption in many cases of the notion of a "national system of innovation", linking science and technology with poverty reduction strategies and (more recently) with the Millennium Development Goals and at the substantive level, identifying biotechnology, ICT and nanotechnology as priority areas.

A concluding comment: The existence of science policies in many countries in our study does not of course mean that these are either effectively pursued or very clearly manifested in actual S&T performance. As our country studies show, in many countries these policies are still rather "vacuous" documents that are referred to mainly in symbolic fashion with little or no effect, mainly because of a lack of resources and (in some cases) lack of will to give expression to the goals and objectives of these documents. Perhaps the best illustration of this phenomenon is the fact that many of these policies and associated plans have set themselves the target of expending 1% of GDP on R&D. Not a single country in sub-Saharan Africa has achieved this target yet.

On a more positive note it is worth pointing out that there is great interest in many of the smaller countries for assistance and expert advice on further science policy development. Countries such as Ethiopia, Tanzania, Malawi, Lesotho – to mention a few only – have reached out to international agencies (including UNESCO) for assistance in the further development and articulation of their science policy and governance frameworks and structures. This is certainly an area that deserves more concerted effort in the future.

B. The institutional landscape: institution-building or de-institutionalization?[52]

Different science systems have very different institutional arrangements and forms. Modern science systems have evolved very differently in different parts of the globe and have produced very different types of research institutions.

In their earlier studies on this theme Waast, Gaillard and Krishna[53] discuss the emergence of "national modes of scientific production" and how these manifested itself in some African

[52] Interesting studies on this theme are found in the special issue of the Journal "Science, Technology and Society", 8:2 2003, about Nigeria, Tanzania, Madagascar and Mozambique as well as Morocco or Tunisia.

countries (Kenya, Nigeria and South Africa) after having achieved independence. .For them a “national mode of science” (Waast and Krishna, 2003: 160) has the following characteristics:

1. Science is for the public good
2. The state assumes a major responsibility for financing research and development activities
3. The direction of that science is determined by the country’s most pressing needs
4. Research scientists and particularly the scientific elite are mostly civil servants and have the right to pursue careers
5. They are imbued with national values as well as professional ones
6. Besides the peer community, the recipients of the products of research are principally the public authorities. The direct users of the products are hardly involved.

In their assessment, by the 1990s much of African science stood at a “very delicate position of crumbling both professionally and from the perspective of institutionalization of science as we conventionally understand it”(op cit. p. 161)

We would agree with these sentiments and add that most modern science systems have a number of typical features:

- There is a core of relatively stable and well-resourced scientific institutes
- There is consistent government and industry investment in these institutes
- Scientific institutions (both formal and informal) flourish under conditions of economic and political stability and within a science governance system that allows for their autonomous and relatively independent operation

Unfortunately, few or none of these “conditions” apply consistently to the seventeen countries in our study. Many of the scientific institutions in the developing countries of sub-Saharan Africa are:

- Fragile and susceptible to the vagaries of political and military events
- Severely under-resourced
- Suffer because of a lack of clarity and articulation of science governance issues (demonstrated by constant shifts in ministerial responsibility for science)

In fact, one could even refer to some of these science systems and the associated institutions as operating in a “subsistence” mode where they struggle to even reproduce

[53] J. Gaillard et al (1997) *Scientific communities in the developing world*, New Delhi: Sage; R. Waast & VV Krishna “Science in Africa; From Institutionalisation to Scientific Free Market- What Options for Development ?”, *Science, Technology and Society*, 8(2): 153 -182, 2003.

themselves. By a “subsistence mode” we mean a system that basically produces knowledge for its own use only and does not export knowledge and in fact does not make a significant contribution in the global game of knowledge production. In fact, it is debatable whether one can talk of a science “system” in many of these countries as they do not exhibit typical “systemic” characteristics. Institutions are not typically aligned through input, process and output flows and there is no typical systemic behaviour in response to external changes and demands. Rather, the image of an “assemblage” of fragile, somewhat disconnected and constantly under-resourced institutions is perhaps a more apt metaphor to describe the science arrangements in some of these countries.

But one should be cautious of over-generalization and over-simplification, as there are also instances of small but robust institutions that have survived the vagaries of political and economic instability, of universities that are still producing high quality graduates and supporting pockets of significant science. Before elaborating on these, we turn to a discussion of a few factors that have in the past and still continue to shape and affect the (de) institutionalization of science in these countries.

Our discussion commences with a focus on four major historical influences on the nature of scientific institutions in sub-Saharan Africa:

- The continuing legacy of colonial science in many countries
- The destabilizing influence of political events and civil wars
- The devastating influence of World Bank policies on higher education in Africa
- The role of international agencies in shaping African sciences

Colonial science legacy

Many of the research institutes that were established during colonial rule still exist in African countries. It is now well documented that the role of different colonial powers in the formation of scientific institutions varied greatly across continents. This is both a function of the nature of the institutions that were established as well as the "model" of "colonial" science pursued.

What is perhaps not so clear is how the continuing legacy of colonial scientific institutions in many African countries should be assessed. On the one hand, such institutions had the negative effect of creating a long-term dependency by the African country on the colonial power – long after independence, which led to a neglect in establishing local institutions (Cf. Gaillard's interesting thesis in this regard in his study of the Tanzanian science system[54]). On the other hand, some of the institutes (such as the Pasteur institutes in Francophone countries) remain sites of significant capacity and provide a stabilizing continuity within the scientific landscape of these countries.

Political stability and civil wars

The destabilizing influence of many regional and local political events have led to the closing of scientific institutions (universities) in many countries and effectively put science back many decades. Events such as the civil war in Rwanda/Burundi, the Mengistu regime in Ethiopia, Amin's dictatorship in Uganda, the civil wars in Mozambique and Angola are examples. These events have had different negative impacts on institution building in these countries. In many cases it led to the suspension of overseas research funding (e.g. Sida/SAREC suspending its support to Ethiopia in the late 1990's), the closing of institutions because of lack of government funding and perhaps most notably the huge flight of top academics and scientists to other parts of the world. A good example of the devastating impact on a single institution is that of the University of Makerere in Uganda. Once a major site for internationally recognized good research in the 1950s and 1960s, it suffered because of civil war and lack of government funding in the 1980s and beyond. This has forced the University in the 1990s to take in many more students than it could support (in order to raise some fees) with the result that by the beginning of this millennium it has more than 30 000 students for a campus built for less than 15 000. It is only in recent years that student growth has been capped and a decline in student numbers has materialized.

[54] J. Gaillard "Tanzania: A case of dependent science" in *Science, Technology and Society* 8:2 (2003): 317 – 343.

Structural adjustment policies and economic decline

Various international forces associated with globalization and internationalization of trade in the 1980s and 1990s have had a devastating effect on the economies of many African countries: the decline in export volumes as well as the relative decline in the price of primary products in world trade in the 1980s and 1990s, combined with the mishandling of exchange rates and of external reserves, and the huge external debt overhang together created major resource gaps for the countries of Africa. This put serious pressure on their import capacity and the availability of resources for essential economic and social investment. The results included increased dependence of the typical sub-Saharan Africa country on aid from the developed countries.

As Sawyer put it[55]:

> *The collapse of many national economies in Africa under these forces and the accompanying destabilisation of social structures threw all institutions, including those of higher education, into a prolonged crisis. A variety of structural adjustment programmes (SAPs) were introduced in the 1980s and 1990s to reverse the economic and social crises. The programmes were intended, first, to give freer reign to market forces by removing rigidities in the production, pricing, marketing and exchange rate regimes. They also sought to cut back the role of the state, downsizing it and reducing its reach. All this was to be combined with the rapid opening up of the economy to international competition. The results are yet new challenges to Africa's universities - the downgrading of university funding (in favour of basic education) and the pressure on them to adjust to the severe austerity regimen imposed by the various economic stabilisation policies, at the same time as they were pressured to increase enrolment and maintain quality levels, without commensurate increases in resources …A further factor was the policy of privileging expenditure on basic education at the expense of higher education, a posture reflecting the policy positions of the World Bank and leading donor agencies, and the argument that the social rate of return on investments in basic education was higher than in higher education.*

To summarize: At the same time as university enrolments increased exponentially in many African countries, both government support and external donor aid to higher education was dramatically reduced. The result was quite predictable with many universities thrown into financial crisis, laboratories and libraries not receiving any maintenance, overcrowded lecture rooms and huge flight of the top academics from these institutions. It was only towards the end of the 1990s that these trends were being reversed and government and international aid (most notably through the Partnership Foundation in the USA) to universities in Africa being restored. However, it should be evident that research and scholarship would be one of the main losers during these years!

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[55] A. Sawyer (n.d.) *Challenges facing African universities: Selected universities*

International research and funding agencies

The role of international agencies in shaping and steering science on the African continent cannot be underestimated. In this regard we include both the role of international development and aid organisations such as Sida/SAREC, Norad, Carnegie, Ford, Rockefeller, USAID, IDRC and many others as well as the presence of international research bodies such as the CGIAR institutes, WHO research institutes and so on. On the positive side, these institutions and agencies have to a large extent, managed to sustain a minimal scientific production in many countries where the formal S&T structures (universities and government research laboratories) have failed or seriously declined. So, for example, it is clear that the continuing support of SIDA to Addis Ababa University in Ethiopia since 1976, has sustained a minimal scientific output in the natural and health sciences. On the negative side, it could be argued that some of these organisations and agencies have been more interested in pursuing their own (international) research agenda's and have not done enough to ensure the long-term sustainability of a local science base in Africa.

What have emerged from our seventeen country studies on scientific institutions? Although somewhat "untested" a first typology of institutional strength and scope can be proposed:

Type 1: The smallest science systems on the continent often rely heavily on the role and contribution of one (or a few) public universities as the main producers of knowledge. In countries such as Namibia, Botswana and Lesotho there are no significant research institutes outside of the national universities and 80 – 90% of the small research output is generated by academic staff at these institutions.

Type 2: Some countries have – in addition to a fairly strong public university (Makerere in Uganda, Dar es Salaam in Tanzania, Addis Abeba University in Ethiopia and so on) also some government funded research institutes and/or international research institutes based in these countries. However, it is not always evident that there is a strong connection and collaboration between staff at these universities and research workers in the local institutes of international agencies (CGIAR or WHO institutes).

Type 3: A few countries – Kenya, Ghana and Senegal – have a larger array of scientific institutions (a number of public universities, government funded laboratories and institutes and internationally based agencies).

The critical role of international research organisations in Africa

Although not always evident from the individual country studies, the very important contribution that international research organizations make to scientific research in Africa cannot be ignored or underestimated. It is also very clear that countries which house the headquarters of these organisations or significant institutes thereof, benefit immensely from their presence. The significance of international institutes is manifold:

- They provide some continuity in research programmes in the countries where they are located
- They are conduits for R&D funding through their international donors
- They form networks of collaboration and expertise that cut across national boundaries
- They provide employment to local scientists in countries where research employment is limited
- They usually have much better facilities and laboratories for conducting research than the local universities and research institutes of the host country.

On the downside, except in very general terms, one could not speak of a close alignment between the research priorities and programmes of these institutes and the national R&D priorities of individual countries. These institutes do not fall under the governance of the national science system of the host country and cannot be said to contribute in any strong sense to national institution-building. The research agenda's and priorities of these institutes are usually set at a supra- or inter-national level. So although their presence in these countries has a positive impact on science in those countries and in the regions and there have been well-documented success stories, in the final analysis they remain disconnected "from the "national science systems" of these countries.

Concluding comment: "Assemblages" of science

What kind of science is being practised in African countries? Our analysis, based on the meta-reviews, suggests a three-fold typology[56].

- Academic science in the universities
- Consultancy science for international (overseas and locally based) organisations
- Mission-oriented science mostly in international agencies (WHO, CGIAR institutes), but also in some cases, in government-based laboratories.

"Academic" science refers to science done by individuals or groups of scientists within universities. Our sense is that much of this science is under-funded, driven by the individual's scientists priorities and interests and is ultimately aimed at advancing the career of the individual academic. This kind of scientific endeavour rarely converts into building institutional capacity since it is not linked, for example, to a group of doctoral or even post-doctoral students. It is therefore not accumulative over time and does not culminate in the building of a programme or centre of excellence that can act as a platform for future

[56] This typology is similar to an earlier analysis by R. Waast and J. Gaillard R. Waast & VV Krishna "Science in Africa; From Institutionalisation to Scientific Free Market- What Options for Development ?" in *Science Technology and Society* 8(2) 2003: 153-182.

research and post-graduate training. Again, there are exceptions such as the highly successful Ethiopian Flora project that has been supported by Sida/Sarec since 1975. But it is precisely because of the international support that one has seen the development of a niche area which accumulated expertise over time.

“Consultancy” science is self-explanatory and refers to the wide-spread occurrence of academics engaging in consultancy work – mostly for international agencies and governments – to augment their rather meager academic salaries. This is perhaps more prevalent in certain disciplines – health sciences, business studies, ICT, monitoring and evaluation work – but is still widespread and on the increase.

Mission-oriented science conducted within the frameworks of international agencies as described above. This is typically Mode 2 science driven by concerns of application and innovation, where the research agenda's are set by non-academics (including foreign boards).

The end result of this picture is clear: lack of funding and interest in classic fundamental science which builds a knowledgebase in a discipline, very little output in academic journals and insufficient attention to the reproduction of scientific capacity through doctoral and post-doctoral programmes.

C. Current state of human and infrastructural resources

General concerns in the human resource area include poor pay and conditions, resulting in a serious and continuous brain drain problem, within the sector, to other non-science sectors and abroad to developed countries and increasingly also to South Africa as a preferred destination. Research infrastructure is often in a poor state with obsolete laboratories and equipment at many research universities. International support is still mainly aimed at human resource development and less directed at funding laboratories and research infrastructure. One of the continuing and sustained challenges for human resources development in science and technology is the persistent brain drain. The continuing seriousness of this issue is illustrated again by the fact that the Association for African Universities (AAU) devoted its most recent meeting in Tripoli in October 2007 to an extensive discussion of this matter. We elaborate on some of the issues and challenges below.

5

On the brain drain

Of the 150 million migrants in the world, more than 50 million are estimated to be Africans. However, a recent report submitted to the United Nations suggests that there are 191 million international migrants in 2005, with those living in Africa accounting for only 9%. In terms of skilled migrants the report notes that there were about 20 million migrants with tertiary education and aged 25 or over living in OECD countries in 2000, which is up from 12 million in 1990 (UN, 2006). The extent of human capital outflow from Africa has been described as staggering given that the level of training and research infrastructure and resources available in most African countries is not comparable to the developed and newly industrialising countries. (Mouton, J.; Kulati, T. & Teng-Zeng, F. [2007] *Scientific mobility and the African diaspora. Working Paper)*

Studies sponsored by the Research and Development Forum for Science-Led Development in Africa (RANDFORUM) reveal that up to 30% of African scientists – i.e. excluding other professionals – are lost due to the brain drain (see Adeboye, 1998). Given the gravity of the situation, therefore, the brain drain of scientists and other professionals from Africa was the subject of a discussion at a "Regional Conference on Brain Drain and Capacity Building in Africa" organised by the United Nations Economic Commission for Africa (UNECA-ECA) in the Ethiopian Capital, Addis Ababa, in February 2000 (ECA, 2000). According to the ECA and the International Organisation for Migration (IOM), an estimated number of 27,000 skilled Africans left the continent for industrialised countries between 1960 and 1975. During the period from 1975-1984, the figures increased to 40,000. Since 1990, at least 20,000 qualified people have left Africa every year (*Education Today*, 2006:4). Accordingly, Alex Nunn of Leeds Metropolitan University notes that this situation makes Africa 20000 fewer people who can deliver public services and articulate calls for greater democracy and development (cited in *Education Today*, 2006:4).

While migration affects all professions and sectors of socio-economic importance, the brain drain in the health and higher education sectors in most developing countries as well as the so-called emerging economies is now receiving much critical worldwide attention. For instance, it has been estimated that about 60% of doctors trained in Ghana during the 1980s have left the country, with 200 of them leaving 2002 alone. [57] Also, a study of the 1995, 1996 and 1997 graduate cohorts from the College of Medicine of the University of Nigeria totaling 468 of which 416 graduates were located shows that 40% of the medical graduates were presently living abroad (including 50% of the female graduates).[58] In 2003, the United Kingdom alone-approved work permits for 5880 health and medical personnel from South Africa, 2825 from Zimbabwe, 1510 from Nigeria, and 850 from Ghana even though these countries have been included among those proscribed for the UK National Health Service (NHS) recruitment.[59]

[57] Sagoe K as cited in Eastwood, JB, RE Conroy, S Naicker, PA West, RC Tutt and J Plange-Rhule 2005. "Loss of health professionals from sub-Saharan Africa: the pivotal role of the UK", the *Lancet* 365: pp. 1893-900.
[58] Chikwe Ihekweazu, Ike Anya and Enyinnaya Anosike 2005. "Nigerian medical graduates: where are they now? The *Lancet* (May 28): pp1847-8.
[59] JB Eastwood *et al* 2005, p1893.

However, some scholars and analysts are now emphasising the importance of the brain gain in Africa, but there is still a long way to go before Africa can reverse its brain drain into positive brain gain. The irony is that with the current outsourcing of certain industrial activities and therefore jobs in some developed countries to developing countries, it is countries with high-level scientific manpower such as India and China that stand to benefit most. Few African countries can take advantage of the situation, because of limited fields of knowledge and limited capacity for rapid expansion as a result of the poor educational and research infrastructure in both the public and private sectors.

D. Informal S&T structures and scientific communities

The "health" of a national system is sometimes gauged not so much by the formal policies, governance arrangements or robustness of research performing institutions, but by informal structures and organisations. In fact, the question is whether there is a discernible scientific community of scholars (for an early statement of these issues see Gaillard and Waast, 1993[60]) which is active and vigorous. "Indicators" of the activity of such communities are not difficult to identify:

- A strong culture of national conferences and seminars
- A sustained tradition of scientific journals published within the country with strong science communication networks
- Active national societies, professional associations and national academies

In addition one could mention programmes and initiatives around promoting science (science awareness campaigns) and rewarding and recognizing scientific excellence (prizes, medals) and so on. Most well-established and well-articulated science systems comprise such scientific communities and the associated features listed above. Our country studies for sub-Saharan Africa have shown, on the whole, however, that very little of these features are present in these science systems. We will elaborate on one issue - scientific journals.

Very few countries have sustainable capacity for local journal publishing. In fact our research has shown that the only ways that these countries seem to be able to sustain some national local journals is (1) through international funding (e.g. Sida support of 26 Ethiopian journals) or the presence of international institutes in the host country which have the resources to publish a journal or (2) the publishing in-house university journals that mostly cater for the university staff. In the latter case, such journals have no aspirations to becoming international journals. Our studies have also shown that many journals typically start at some point, but eventually run out of resources for its sustained continuation. As an

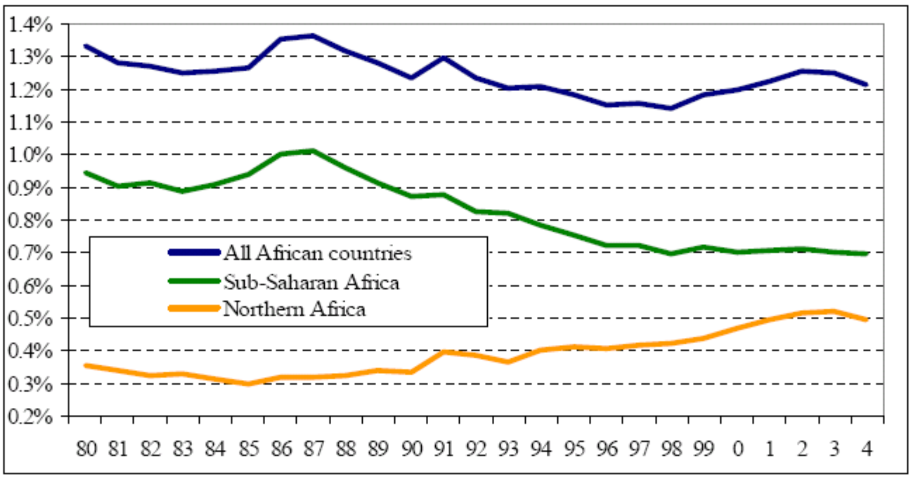
[60] J. Gaillard and R. Waast, "The uphill emergence of scientific communities in Africa" in Aqueil Ahmad (Ed.), Science and technology policy for economic development in Africa, International Studies in Sociology and Social Anthropology, pp. 41- 67, 1993.

example of a poor country with a rather active science base, one can refer to Burkina Faso where researchers have at their disposal several journals that they try to maintain even if funding is very low.

E. Knowledge production and output

It is by now well known that Africa's share of world science as measured in papers published in ISI-indexes have been declining steadily over the past decade. Various earlier studies by Gaillard, Waast and other have looked at this issue, but arguably the most comprehensive and up to date bibliometric analysis of these trends is captured in Robert Tijssen recent 2006 article in *Scientometrics* (*Africa's contributions to the worldwide research literature: New analytical perspectives, trends, and performance indicators).* In his analysis, Tijssen shows how sub-Saharan Africa has fallen behind quite dramatically from 1% in 1987 to 0.7% in 1996 with no sign of recovery (Figure 1). These diminishing shares of African science overall do not reflect a decrease in absolute sense, but rather an increase in publication output less than the worldwide growth rate. Africa has lost 11% of its share in global science since its peak in 1987; Sub-Saharan science has lost almost a third (31%). The countries in Northern Africa; Egypt and the Maghreb countries (Algeria, Mauritania, Libya, Morocco and Tunisia) accounted for the modest growth of the African share of the worldwide output during the years 1998-2002. Part of this decline of Sub-Saharan science can be attributed to discarding African journals from the *Citation Indexes*. Notably, the number of South African journals dropped from 35 to 19 during the years 1993-2004.

Figure 1. Trends in African research article output in the international journal literature (1980-2004): % of worldwide publication output in the international peer-reviewed journal literature.



Source: CWTS/Thomson Science Citation Index database (excluding the Arts and Humanities Citation Index).

In a detailed analysis of the individual citation profiles of a selection of countries, Tijssen shows how unequal knowledge production is across the continent. For example, within the group of the seven largest countries, South Africa and Kenya are clearly out-performing the other five in terms of average citation rates, the share of publications cited, and the field-normalized citation scores. As Tijssen argues, it seems reasonable to assume that this performance is partly a cultural heritage from their English-language science systems that help to sustain or enhance their visibility in English-language dominated international research literature. The Northern African countries, traditionally more focused on the Arab world and the French-speaking scientific world, are at a disadvantage.

And finally, Tijssen also show that there is surprisingly not a strong correlation between the country's level of technological development and any of the scientometric indicators. A positive correlation coefficient exists between the ArCo index value and the level of publication output (r=0.51), but all other indicators show negative coefficients (ranging from r=-0.28 to r=-0.50). In other words, size is inversely related to citation impact; the smaller African countries are receiving relatively large numbers of citations compared to the largest countries, in large part owing to their international co-publications in fields of the medical and life sciences.

This is especially true for countries such as Gambia, Mali and Mozambique who recorded above average citation scores albeit with small production. In cases such as these, it would be essential to look more closely at (1) who these authors co-author (as this is a huge factor in citation visibility) and (2) the nature of the institutions where these scientists are based. In terms of our earlier discussion on scientific institutions, it is more than likely that some of these scientists are based in international research organisations based in the host country and that they are benefiting from long-established networks with scientists in France, Sweden, the UK and other northern countries. In the final analysis, however, it remains the case that both the output of African science in international journals is declining and that its overall visibility globally is minimal. African science in many respects is science on the margin: invisible and unrecognized.

CONCLUDING ASSESSMENT

Our seventeen country reviews have raised a number of critical issues and highlighted many challenges that African research faces. I conclude with some summary points:

- Our country reviews have utilized and exploited as much of the available information and documentation of these countries possible. Some country visits were possible (although not required under the Brief) which augmented the available statistics. However, there is a dire need to conduct follow-up country visits not only to improve the quality of the statistical data, but also to gather more qualitative and narrative information on scientific communities in these countries, the social inscription of science and status of scientists in the countries and so on.

- Our review of African research systems has reiterated the need for support in policy development. It is evident that many countries and ministries of science and technology require capacity building and technical support in various aspects of policy development, implementation and monitoring and evaluation.
- The quality of national statistics and indicators on higher education and science and technology needs to be prioritized. We strongly suggest that the possibility of establishing a network of observatories for science and technology in African be investigated.
- Ways and mechanisms should be investigated of raising the visibility of African science. In addition to support for local journals and journal development, it would be advisable also to investigate the more intensive use of advanced web-based solutions such as virtual repositories, a knowledge commons for peer-reviewed materials and so on.

3.2 ARAB REGION REPORT

This Report draws information from monographs, books and journal articles less than ten years old and dealing with the status of S&T in 11 Arab countries. We have compiled in our "Meta review" the best of them[61].

The countries dealt with are: **Algeria, Morocco and Tunisia** (called together the "Maghreb" sub region); **Lebanon, Jordan and Syria** (called together "Machreq"); **Bahrain, Kuwait, Oman, Qatar and United Arab Emirates** (called together "Gulf" countries)[62].

Information is clearly uneven. In some cases we came across good and detailed monographs (as for Maghreb countries, mostly in French). In other cases we had great difficulties to find coherent and comprehensive data (if any). The Gulf countries are an example, and also Egypt and Syria (we found reports on specific aspects). One lesson is that *there is an urgent need of* data and standardized studies in the region, indeed of "*Observatories* of S&T" as those some countries contemplate establishing (Tunisia, Lebanon, Morocco).

Fortunately, we could rely on some recent and excellent surveys of the zone:

> * One source is the complete range of substantial monographs dedicated to "*Science in Africa*" (a European project about 15 countries, including Morocco, Algeria and Egypt)[63]. All these monographs can now be unloaded free of charge from www.ird.fr/fr/science/dss
> * Another generous source (up to date) derives also from a European project. This ESTIME project was managed by R. Arvanitis and targeted 8 Mediterranean countries. It involved numerous teams of the region, and the contribution of science officials in each country. The aim was to describe the science systems, the uses of research, and specifically the activity of human and social sciences. A number of reports have been issued and they can be unloaded from www.estime.ird.fr/
> * In spite of many difficulties, S. Hanafi gathered a range of facts about science in the Gulf countries (even when there are not policies in the strict literal sense of the word).

[61] Most complete and recent, in English, restricted to one item for each country.
[62] **Egypt** is dealt with in this Report, though we could not find any comprehensive monograph recently completed on that country. We had to draw from a good monograph of 2001 (originating from the European "*Science in Africa*" project) and scattered data (national and international sources). We could not find reliable data on Iran; we replaced it by information on *Qatar* which was not in our brief but should clearly have been included
[63] M. Kleiche authored *Morocco*, H. Khelfaoui *Algeria* and S. Radi *Egypt*. Monographs are in French, but the best pages were published in English by the *Science, Technology & Society* journal (8/2 and 9/1, 2003 and 2004).

> We added to our investigation a number of *bibliometric analyses* (See regional Report). This went beyond our brief. But they offer an interesting view on the output of research in the region, and its positive development.

Let us now come to a general view and to summary findings from the country profiles.

1. General view.

The paradox in this part of the world is that one comes across obvious talents, pulling greatly the output upwards; while no specific goal is commonly ascribed to research. The social inscription of science remains unsteady and the proper *function* of research is vague.

Moreover there are great differences between sub-regions (the Gulf countries, Machreq, Maghreb) and even between countries[64] as for the age and context of scientific activity, the socio cognitive blocs supporting it, the nature of institutional arrangements, financing and organizing solutions.

Historical setting.

In this region of ancient and brilliant civilisations there are still powerful memories of the glorious past when science in the Arab states and Muslim Universities was much ahead of the rest of the world: in mathematics, chemistry, optics, medicine as well as philosophy and literature. However, after ten centuries of a stormy history, the revival of science and technology in their modern form links up with an interaction with foreign imperialisms. They were brought in by the Ottomans in the Near East, by colonisation in the Maghreb. But they were only significantly institutionalized after the decolonization (which came in Machreq as early as the 1940s, and years later in Maghreb[65]). It is not before the 1970s or often the 80s that mass universities and numerous research centres were set up and a visible scientific production began to grow quickly.

Egypt is an exception. Modern science and technology were naturalized in advance, to capture their power and preserve independence. Medical and Engineering Schools were set up as early as the 1820s and their alumni achieved technical feats (railway, irrigation…) that did much for the reputation of the scientific professions. A private university was established in 1908 by nationalists, in order to mould the national elite. After independence (1922), it was confirmed as the (prestigious) public University of Cairo, which had been preceded by another private elite institution (the American University of Cairo). As early as 1928, a Higher *Council for Scientific Research* was put in charge to propose, assess and encourage work in veterinary, agriculture and health sciences. It got a budget after the 2nd World War.

[64] Egypt being a peculiar case, as the oldest and largest producer of science in the region.

[65] Colonisation in the Arab world assumed very different forms and lengths, from a long populating occupation which lasted 130 years in Algeria and was overthrown through a fierce war, to short protectorates (30 years in the near East) or indirect rule (70 years in Egypt) ended through international negotiations..

And the 1950s saw the establishment of sizeable public *laboratories* for basic sciences within a National Centre for scientific Research and the Atomic Energy Committee. Universities also (Cairo and now Alexandria and Ain Shams) were keen to do research. Gradually the system grew and became a mass tertiary education apparatus. Polytechnics were founded (1950s & 1960s) then a new wave of Universities and Research institutes (1970s). Egypt can thus boast a long tradition in research, with decades of visible results (publications) and strong points (especially in engineering sciences, chemistry, and mathematics)[66].

No other part of the region can trace such a national scientific history. But some countries in the Near East have old and worthy *establishments* which continue to play a major role in their scientific achievements. They are mainly Universities. Two of them are in Lebanon (and private): the Saint Joseph University, founded in 1875 and which for a long time dedicated itself to Law, Economy and the training of local political elites; the second one is the American University of Beirut, set up as early as 1867 and which at first specialized in more "technical" sciences (medicine and agriculture) for Arab clients of the whole region. The Damascus University is an old one too (set up in 1903)[67]. Elsewhere, the story of Universities is recent, beginning with independencies and aiming to train the managerial staff much needed after most of the colonial executives left. Few of these establishments became "research universities"; and this is not yet the case for many of the "young" and private Universities founded during the 1980s or 1990s (especially when they are market oriented, just aiming to meet the demand for skills and catch a number of students and fees as is often the case in the Near East[68]). At the same time, Research institutes (some of them inherited from the colonial powers) have been repopulated with national scientists and there was a vogue for their creation in the 1980s and 1990s (especially in Maghreb).

In all cases Maghreb (due to a late colonisation) was clearly behind Machreq at the beginning of the 60s, and Machreq and the Gulf behind Egypt. But the main institutionalisation of science remains everywhere a recent one (dating back to 2 or 3 decades).

Social Environment

Even where there is a long tradition of research (Egypt), the social inscription of science remains unsteady. The societies are strongly framed by communities, lineage relations and religious belief. Furthermore, the political sphere is dominant. A resounding report from

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[66] Egypt too is since a long time a vibrant place for "Human and social sciences" (teaching, research, publishing, ideological debate) with establishments as the very old and prestigious University Al Ahzar, and intense moments of philosophical, political and religious creation.

[67] Algiers University was established in 1903 too. But it never trained any significant number of "Muslim" students.

[68] Maghreb universities are less market driven and most of them do some research and built strong points in specific areas.

UNDP, written by authoritative experts from the region[69], recently marked out inadequate relationship with knowledge as one of the two or three main handicaps hindering progress in Arab countries. They blamed for it the spirit of both school and family education (influencing the very style of scientific activity and making little room for creativity), and the status of knowledge (held in low regard – in societies dominated by political and lineage values).

A number of monographs insist on the fact that common values play down the worth of knowledge (except for the religious one) and discredit efforts to broaden it. Jordan is a well documented case.

> "The social understanding of science considers obtaining a PhD degree as the end of the process of reading and researching. The degree rather than the record of scientific research is what gives the person a social status in the society (and even in the university). The social view that sees the university faculty as capable of exercising certain forms of social and political power encourages many people to seek for his assistance. Family and neighbours of the researcher regularly visit her/him in the office on campus to ask for some favours and services. The position of the researcher within the social power network and her/his ability to exercise power within this network are for him a permanent concern.[70]"

Maghreb is somewhat different, as research has become part of the role model of respected *professions* (or of their recognised elite: academics, professors of medicine and high flying engineers). Nevertheless "multiple irregular commitments of other nature prevent the researcher from concentrating on his research and from spending continuous time to process the data". In all countries, "social factors play a big role in impeding scientific research or limiting its efficiency".

Support to Science

Amidst adverse context (insecurity and political unrest could often be added) science grows nevertheless. It can't be so without entering into alliance with social groups, which see their own position and struggles in the society as analogous to those of science in the world of knowledge. Thanks to their support it becomes possible to avoid the obstacles and devote to a scholarly life.

Among these "socio cognitive blocs" the main one is that linking *the state* (or fractions in power) with the cause of science. Either as a symbol of modernization (Gulf), of rationality (Tunisia), of uniting the people under a nation state (Syria), or because it was part of the development model (Nasser: Egypt) many governments at one time or another granted strong support to the blossoming of tertiary education and research (especially in "hard

[69] UNDP. Human Development Reports: Arab countries.
[70] ESTIME Project: Jordan country report: www.estime.ird.fr

sciences"). It should be stressed that such a support can't be taken for granted. It depends on the regime, the fractions in power, and there were indeed many turnarounds.

> Algeria is a good example. While it paid little attention to University and none to research after independence (concentrating on primary and secondary education), it promoted vigorously a "scientific option" after 1975. A number of Polytechnics were opened, Universities of S&T created, enrolment grew quickly, and a national body for driving research (ONRS) was granted a large budget. These efforts were due to the weight in the government of a faction of "technocrats", who tried to launch a heavy industrialisation of the country in order to make it independent and prepare the post petroleum era. Their opponents were "patrimonialists", who considered there could be no autonomous development before the recovery of an authentic culture (original language, religion, values…) and put priorities elsewhere. The development of "Science" was objectively linked to the first ones[71]. When they lost their footing (after 1980) scientists lost their credit, many of them had to leave the country; a few of them managed to stay and tackled with a will to maintain the scientific community. But changes affected the governing bodies of research and budgets were severely cut. It is only since a very few years (after the end of the civil war) that a new strong effort for research has been scheduled, with striking results, by the current modernizing government.

A general characteristic of the region is that the support of the state may be powerful, but it has *ups and downs.* In many places it is discreet (Machreq and the Gulf) but it should be acknowledged that almost everywhere the state did a great deal for research through regulations (especially the subordination of promotion in academic careers to some research work); and with few exceptions (Egypt and Algeria), governments never treated the profession poorly.

An (alternative) support for science lies in *professions*. This is notably the case again *in Maghreb*. Professional groups, that did not exist before independence, have developed quickly. They proudly maintain high standards and they have integrated research into their role model – offering shelter to researchers when the state support weakens [72].

Another support may come from outside. *International* pressure and advice have been instrumental in setting up governing bodies and adopting favourable regulations[73]. International scientific cooperation helps keeping the scientists up to date and supplements

[71] El Kenz, "Prometheus and Hermes" in Shinn, Spaapen & Krishna *Science and Technology in a Developing World*, Dordrecht:Kluwer1997:323-348; for Tunisia see Siino "Tunisian Science in Search of Legitimacy" in *Science, Technology & Society*, 8 :2, 2003, 261-281

[72] See Waast for medical practitioners, Khelfaoui for engineers and for academics: Waast "Médecine recherche et protection sociale" in Curmi ed. *Médecins et protection sociale dans le monde arabe* Cahiers du CERMOC, Beïrut (1993): 83-99. Khelfaoui "Scientific Resaerch in Algeria: Institutionalisation versus Professionnalisation" in *Science, Technology & Society*, 9 :1, 2004, 75-101

[73] They also helped to create "Mission Centres" in fields of world-wide interest (geophysics, epidemics, etc)

finances. In some disciplines, international demand for research gave rise to a recent upsurge in (private) research “Centres”, and employment in that branch. This is typically the case in Machreq, for social sciences.

Finally, one can identify support from specific communities or social groups (liberal elites in Egypt and Lebanon, important families in Gulf countries, technocratic strata in Algeria…). This is idiosyncratic but matters a great deal locally (grants, political support…).

All these modes of support are important. But none is decisive or really stable. Finally, the visible growth of results *stems from the professional norms* internalized by a few individuals and some establishments that maintain a research culture. As we’ll see they need new encouragements.

Diversity

We already identified some common features. It should now be recognized that there is a great variety among Arab countries. Their relative identity stems from a common language, the dominant religion and the joint heritage of ancient arabo-islamic civilisation. Their unity is more of a cultural and symbolic nature and does not rely on institutional substance.

History, economics and the different regimes have carved out distinct zones. Even neighbouring countries in this region have a different endowment in natural resources and their own development strategies (past and present), which make them very diverse. This bears upon their very attitude toward science and education. In broad outlines, one may distinguish ***three main zones*** (with a lot of variations inside): the Gulf countries Machreq and Maghreb. Egypt is a case by itself.

* As soon as they were independent, most of the ***Gulf countries*** adopted an “anglo-saxon model” with elite universities, and research programs in experimental sciences (widely open to collaboration with foreign countries – mainly USA and UK). In human and social sciences, research programmes were on the contrary “closed” (reserved for local language and scientists). In both cases a pragmatic form of science expanded, connected to local problems: chemistry, biotechnologies, computer science; sociology (in fact social engineering), micro economics, and Islamic philosophy or law. Research is not here of real need (for the economy depends on royalties from oil and linked remittances[74]), but rather the vestment of Universities (and an ornament for donors). It has been funded by some states, and numbers of *Foundations*. It is mostly operated by foreign professors, sometimes

[74] As some of these countries are preparing for the « after oil » era, they turn to an economy of trade and services rather than to innovative industry. They are not in need of more research (at least in hard sciences, if not in economics and modelling mathematics, which gain ground).

by prestigious invited visitors, who were hired in greater and greater numbers as the Universities increased significantly.

* ***Egypt*** (and other countries in the Near and Middle East like Iraq or Syria) set up soon a mass education system, including tertiary education, with a view to train the technical workforce needed by their development model (mass production for internal market). As this “Fordian” model failed they entered hastily into a reconstruction of the education system. Private Colleges and Universities proliferated[75] while the public establishments, overcrowded and ill funded, lost quality and their staff saw a drop in status and wealth (especially in Egypt). A number of academics and researchers left (at least temporarily) to the Gulf countries (where there was a growing need and good pay for their skills) and / or concentrated their activity on consulting and expertise[76]. National Institutes (outside Universities) are important performers here. But their budget was reduced and they now have to become more and more self-financing. This rule is imperative for the research centres established by the main Universities in their own walls. They too have to get funded by external contracts. These new dynamics altered the academic hierarchies and disciplinary requirements for the benefit of networks based rather on patronage.

* In the ***Near East*** (Jordan, Lebanon) though no “Fordian” ambition prevailed (their internal market is indeed too small) the *private spirit* was pre-eminent much earlier. Most Universities are private ones (since the 90s in Jordan, and long ago in Lebanon, where the only public one – “Lebanese” – gathers half of the students but was set up only in 1950, one century after the first private and prestigious establishments). There are almost no national research Centres, except small ones in very specific areas (seismic survey, transport). But University laboratories depend on private Foundations (and make a living on contracts, manly delivering services or development research, rather than applied or strategic ones). Recently, a host of “commercial” research centres have been created in the social sciences to meet the important demand of studies by international bodies (UNDP etc about the Palestinian camps and integration, political situation etc). Here, research should be clearly marketable. Other norms for it are only maintained in a few establishments, increasing their honour and prestige (and providing a label which attracts students and financial resources). These are a few “research universities” (like AUB in Beirut or JUST in Jordan) or reputable Foundations (like the Royal Scientific Society in Amman).

* ***Maghreb*** is different. Though latecomers, Morocco, Tunisia and Algeria quickly established mass universities of quality throughout the country (after 1985), and a number of prestigious Polytechnics (selective, for all sorts of engineers). They set up in parallel

[75] Except in Syria.
[76] Meeting the new demand of international bodies and enterprises (World Bank, Occidental Foundations in the social sciences; Pharmaceuticals and computer industries…

national Centres for research in various fields (agriculture, health, and later telecommunications, energies, nuclear technology or materials). Their model (institutional and intellectual) draws inspiration from Europe (especially from France) and intensive scientific cooperation has unfailingly supported their activities. State control is strong; governments are secular and nationalist with a technocratic ethos. They launched and financed the system (though through eclipses) without the private sector managing to carve a significant share of the activity. Scientific talents and vocations are not lacking, and research was soon professionalized. There is some R&D in enterprises (more so in large state owned ones, especially in Algeria). Innovation and technology are values among the high technical civil service and research (pure or applied) is part of the role model of academics[77]. There are variants in this sub region. Tunisia was most constant in its support to science, and has recently developed a full set of institutions framing research, which is lacking elsewhere (See next section).

After this bird's eye view approach, we shall now concentrate on more particular features: Governance and Policies; Institutional Framework; Human Resources; and Output of research.

2. Governance and Policies.

The first national research authorities date back to the 1970s (Algeria, Tunisia), or the 90s if not the 21st century (Syria and the Gulf)[78]. By now, it is possible everywhere to identify some higher body dedicated to "Research".

Not all of them are concerned about elaborating policy documents. Some countries did it. Morocco and Lebanon even elaborated "visions" for the long term, involving a number of stakeholders in debates that lasted for more than one year. Those briefs are instructive. But they rarely depend on a detailed knowledge of the scientific capabilities established in the country, and an imaginative distinction of the opportune niches that could be derived from them. They need to be translated into strategies.

Instead of holding forth on these texts we think it more useful to insist on three points:

- there are two different approaches to the governance of science
- they lead to different strategies
- in all cases the function of science remains questionable, and the research system is fragmented.

[77] Their carriers are linked to achievements in this field.
[78] See Descriptors. Egypt and Lebanon again came earlier.

a) Two main approaches: Centralised governance or grassroots initiatives

There is a great difference between two main approaches.

In Egypt and the Maghreb, there is a strong role of the state in the management of the research sector. The state created most of the establishments likely to do some research (Universities, Centres), specified the status of their personnel (who are mostly civil servants) and keeps them all under control[79]. Government funding is the main resource for research (either core funding to establishments, earmarked or competitive funds). Moreover, it can be said that the impulse from the state is waited upon by the actors and not only an approval for their grassroots initiatives. This pertains to guidelines on priorities, as well as encouragement for research. This government method is efficient (general impulse, synthetic plans) as long as the state remains strongly committed; but it may cause pernicious effects (like a bureaucratic spirit[80], little initiative of performers and poor networking with local actors). This governance mode can be depicted rather faithfully through organisation charts like those of Algeria or Tunisia (See the regional Report).

The second approach is quite opposite. It prevails mainly in Machreq and the Gulf countries. The *performers* are most important (Universities, enterprises – there are few Research Centres here). Activity relies on their initiative and on their decision to take part or not in research, according to their own interests. National bodies in charge of science are often independent (though their budget almost totally comes from the government). They are supposed to act by persuasion on the basic actors, through incentives, services and working as facilitators. Lebanon and Jordan are good examples (See regional Report).

The most remarkable bodies can be found in the Gulf countries. They are generally very new, and they consist of Agencies or Foundations whose objective is specifically to attract foreign capabilities and R&D firms from abroad. This of course does not prevent a Ministry (of Tertiary education) to assume "governing functions (Bahrain)" i.e. "approve foreign degrees" (Emirates), or "keep track of scientific research undertaken by colleges and institutes of higher education (Kuwait)". But in Kuwait, KFAS (the Kuwait Foundation for the Advancement of Science, whose board is a sort of interdepartmental Committee) is a more important player. It has to provide "funding and coordination for the research", seeing to "the investment of the results in extending development to broader and newer horizons" with the private sector as a main target. The Qatar Foundation was instrumental in attracting

[79] There are policy documents. An interministerial Committee meets more or less regularly (at least once a year) to specify the priorities. A permanent Authority (a Ministry or Ministry of state, at least a special Department) translates them into regulations, legislation, institution building, budget grants and instructions to the establishments. Its arms (Agencies or National services) take action, implement the measures and monitor the situation. But the real authority may be scattered between several Ministries (Agriculture, Health, Mines, Higher Education…), reflecting the fragmentation of the research system.

[80] Khelfaoui (STS 9 :2) speaks even of an « authoritarian control » "crippling bureaucratic impulses" and for Algeria of a « military style control over scientific institutions".

prestigious foreign institutions of higher education[81]; and the Qatar Science and Technology Park (QSTP: the other major R&D public organization) is a “home for technology-based companies from around the world, and an incubator of start-up enterprises”. Emirates are most active along the same path, negotiations being directly driven by the government.

Egypt has a mix of centralised governing public bodies (in fact several of them: a Ministry, the Academy of Sciences, without reckoning other Ministries) and of some powerful performers (like the National Centre for Research, and various prestigious (AUC) or huge Universities – Cairo University being the largest). Governance is complex.

b) Different strategies

The difference between governance modes leads to different strategies.

For Maghreb countries (and Egypt) there is a clear awareness of the necessity to develop first a solid *national science base*. This means first basic science (and they have developed a whole range of capabilities in all sorts of specialties in fundamental sciences) then drawing it toward applied or strategic research (sometimes in specialised Centres) and linking it to the productive sector. Significant efforts have been devoted to this end and numerous mechanisms are on trial. Algeria recently put a lot of money in PNR (National Programmes of Research) in order to attract its scientists into applied projects. Calls for tenders were also used in Morocco. Incentives for enterprises try to encourage them to invest in R&D and link with research performers. There is now the full battery of instruments recommended by international bodies to develop innovation.

Yet, some observers emphasize that “a real research activity is linked to the emergence of a scientific community, and results of a professional rather than an institutional development” (Algerian case: Khelfaoui, 2004: p. 86). This is of course the most delicate challenge for a centralized governance.

In Machreq countries, there is no such problem. On the contrary performers are free of their initiatives (and very often let alone with their own means or unwillingness to take part in the game). The “authorities” have to make the most with their good fortune, namely the specific capabilities existing in the few establishments interested in research and ready to be mobilized. The asset is not always in line with the expectations of a coherent Plan and the strategy is rather to launch open calls for tenders to discover the potential or/and to test it through pragmatic projects.

[81] “Campuses of Carnegie Mellon, Texas A&M, Weill Cornell and other leading universities were created.

Through this process, national authorities "enter a market": they "test" the competition with other (international) donors: for the number of research volunteers is limited, and they reach a saturation point[82]. Human & Social sciences are a special case, as a number of "commercial Centres" and research NGOs emerged to enlarge the offer and meet the large foreign demand in Jordan and Lebanon. As equipment is needed this is more difficult in experimental sciences. In any case, developing a national research strategy is not an easy task for authorities.

The Gulf countries are an extreme case. Their own strategy does not aim at building a national science base; but at *localizing on their territory the best foreign* capabilities, and innovative R&D firms. Qatar has attracted campuses of Carnegie Mellon, Texas A&M, Weill Cornell and other leading universities. Emirates had no less success with Abu Dhabi chapter of the Sorbonne, University Wollongong or Westfield University (not counting the brand new American Universities of Sharjah). They are building giant premises for "Knowledge Universities" (a multi university complex in Dubai).
First members of the Qatari Science park were "EADS, ExxonMobil, GE, Microsoft, Shell and Total. By bringing research and business together, QSTP is delivering Qatar's vision for a knowledge economy". Emirates again established in 2003 a Knowledge Village (KV) in the Dubai Free Zone for Technology and Media. It houses more than 200 companies and institutes for training and education in fields such as computing, technology, business management, life science, fashion and media". A Dubai Academic City (DAC) is marketed as 'a *new global fully integrated academic destination*'[83].

This is an innovative strategy, looking ahead and fitting small countries. It looks like that of Singapore days ago. This is a shortcut to the building of a national science base. Links could be later interwoven with local performers. The main question is whether this new strategy is a sustainable one; or a purely commercial (and rather: financial) one. New campuses are designed to compete with the best old Universities in the region (AUB…) and elsewhere. They are supposed to attract a number of rich and brilliant students[84]; and their assessment is by now much more in terms of profitability than of substantial contribution to education and knowledge. The same is true for R&D firms: no substantive industrial strategy is yet linked to their arrival.

c) Structuring research

Finally, a similar problem arises whatever the governance system. Is there a "research system"? In Arab countries, one could say there are organs for research (Universities,

[82] See Lebanon monograph. The competition is illustrated by the research budget of a prestigious University (AUB) and its sponsors. Same monograph.
[83] "It was officially launched in 2006. Investment in this phased project, which is being built on a 12- million-square-metres campus, is forecast to exceed Dh12 billion (US$3.27 billion). A completion date is set for 2012".
[84] In the Knowledge Village, "25 percent of the students are from countries in the Middle East, whilst other students are from Arab and foreign communities residing in Dubai".

Centres, and sometimes an overabundance of more or less governing bodies) but they don't aim together a specific goal. The "system" is fragmented (indeed there is no "system", but there are many initiatives around small and scattered projects, rather than programmes).

Maghreb countries seem to be the most conscious of this problem of coordination. Notably, *the Tunisian state* has been considering for years research as a specific function and set up a decade ago a whole arrangement of institutions. It is the most complete in the region and *certainly a good practice*.

The critical step consisted in establishing the building blocks of a specific system: "research units" and "laboratories" meeting a strong list of criteria (size, skills structure, proven results) accredited and periodically *assessed* by international commissions. These teams may be bound to a University, or to a research Centre, or cross over the different sectors. They must have a research plan, and they generally combine strategic and applied research. Linked to their accreditation are benefits in kind[85] for their directors, special access to up to date documentation and equipment, and a significant long term core budget. A special state supervision has been instituted for research (directly linked to the Presidency) with growing budgets (now more than 1% of GDP). A number of other institutions were established: an interdepartmental Committee, a national *Commission for assessing* individual researchers, a national Plan stating priorities where important means are invested (telecommunications is an example), incentives for R&D in enterprises and joint funding mechanisms with the productive sector. Of course this system is restricted only to a (small) part of the theoretical scientific potential. Figures of FTE may seem to have declined, but *active researchers* only are counted (as in Mexico and other Latin American countries). The result has been a spectacular and unfailing leap forward of the output[86].

> Other countries of Maghreb have recently taken similar paths but in a less comprehensive or systematic way. There is not only one structuring model. Good practices may begin at a smaller scale and result from limited initiatives by establishments (AUB in Lebanon), Foundations (RSS in Jordan) or international cooperation (through long standing support to research units). The important thing is that research be considered as a permanent function, and that researchers no longer be atomized individuals. Institution building is necessary to strengthen long lasting laboratories that enter into large-scale networking and ambitious international programmes.

[85] Mostly : reduction in teaching or routine work load.
[86] Tunisia is now 2nd in Arab countries, after Egypt but outperforming Morocco.

3. Institutional landscape.

The main research perfomers are either Universities or “mission Centres”. R&D in enterprises is rare.

a) Research: a subordinate function

In all cases, research is **a *subordinate function*.**

If we look first at *Universities*: research is *not* on the agenda of the most recent and private ones[87] (which just concerned with teaching). Among public establishments, only a few are “research oriented” and even there a small portion of the academics regularly produces results. This is well documented through bibliometric studies. The mainspring linking (sometimes loosely) career to research achievements is not sufficient to supersede the fact that research is considered as a minor function (or not a function *per se*) with its correlates: many establishments have no strategic plan for research and very small budgets for equipment, documentation or project operating. They often ignore their own capacities and their laboratories (if there are) are not mentioned in their web pages.

In the *Centres*, time and budget for research generally come after routine surveys have been conducted and a number of services performed (production and distribution of seeds, vaccine production, nuclear waste gathering…). This is time consuming for engineers and researchers, occupying fully a number of them[88]. Often, research is limited to little creative development. Very few Centres are totally dedicated to research and basic sciences[89]. When it comes to making contributions to science other than simple engineering the question becomes that of the critical mass available for a long term effort. Alliances (with academic research among others) would be necessary. But the Centres often prefer in-house operation, in order to keep control on the process and their own staff.

b) Sanctuaries for Research

Thus, much depends on ***the management and culture*** of the establishments. Research needs sanctuaries, and some places offer it a shelter.

A number of “good practices” are worth being mentioned.

In Morocco, all the Universities are now obliged to appoint a “Research Dean” and to submit a “*Research Plan*”, opening rights (if approved) to specific funds from the State. A number

[87] With the notable exception of 3 the old elite and prestigious ones: St Joseph in Beirut, and American Universities (in Cairo and Beirut).

[88] Sometimes, a research plan acts as a safeguard to preserve this activity (as in INRH, Morocco).

[89] A notable exception is the National centre for research in Egypt (with 2 000 researchers). Some other centres practise significant “strategic” or applied research (notably in Egypt and Maghreb. Most of them are small or medium sized institutions:

of Centres worked out strategic plans for research. Some Centres have developed teams of academics *and* in-house researchers to achieve joint projects.
Other solutions are more personally oriented. Prestigious Universities in the Near East have established a “Bureau” (as AUB in Beirut) helping closely the academics to apply for research contracts and manage them. Moreover, tenures are rare and work-contracts are renewed each 4 years only when applicants produce proofs of research (AUB again). At the Lebanese University, the research budget of the establishment was converted into an individual bonus for the staff who submitted their current projects to a scientific Commission and proved they have results.

The objective is to develop loyalty of the staff to local research structures, even if a national structuring is not yet established.

c) International co operation.

International cooperation plays a great role in this context. Research is often pursued on an individual basis. In order to gain access to up to date equipment and documentation researchers often seek the cooperation of foreign colleagues or laboratories. This is also a way to avoid insularity, be exposed to new concepts and hot topics, publish abroad and get some additional funding (especially for travelling and taking part in the world science).

Bibliometric studies show that a large proportion of articles are co-authored with foreign researchers. Such abundance of cooperation[90] is both an asset and a risk: that of becoming a sub-contractor for trivial verifications of front line science, or a pieceworker in leading edge programmes without grasping all of their stakes (economic or scientific). There are examples of well positioned activities (Neuropathology in Morocco, Drugs chemistry in Egypt, Energetic engineering in Jordan etc…) supported by top quality cooperation. But finding anticipating niches (promising short cuts to discovery or/and original innovation) needs a vivid imagination and large scale collaborations. Quite the opposite, detailed bibliometrics shows that most collaborations are going on between small teams and through short networks[91] - most often occasioned by projects, not programmes.

One of the main weaknesses of most Arab research units is their lack of participation in ambitious and far reaching programmes. This is not impossible even in very sophisticated fields. Examples are high energy physics in Morocco, linked to the ATLAS European project; or genetic diseases in Maghreb – through French high flying collaborations. There is

[90] The main partners are European countries (first partner when counted together). France is very active in Maghreb (also in Lebanon and Syria); UK and Germany are oriented toward Egypt, Machreq and the Near East. USA are the first individual partner in Egypt and east of Egypt (very little in Maghreb).
[91] See ESTIME : Bibliometric Report (especially: Atlas of institutions and study of networks)..

a specific responsibility of international cooperation at this level. Small bilateral projects lead to sustaining (and even building) capacities: but hardly to institution building.

4. Human Resources.

As the function of research is not clearly agreed upon, much depends not only on the initiative of establishments, but on the readiness of individuals. The role of professional norms and values here is very important, together with the disposition of individual persons and the appeal of the profession.

a) The Profession.

**** Remuneration***. It must be stressed first that (contrary to the situation in most of the developing world – except emerging countries – the *profession remains attractive*. Academics (and to a lesser extent researchers) are ***not ill treated*** in that part of the world. The monographs give detailed evidence that in Morocco (and even Tunisia), in Lebanon and Jordan faculty members are well remunerated[92]. Salaries in the Gulf countries are even better. Exceptions are Egypt and Algeria. There, the remunerations were dreadfully eroded by price rise; an important emigration takes place continuously; and professionals are often busy with parallel tasks (contracts for teaching or doing research elsewhere) to make their living[93].

* ***Careers are regulated by research achievements.*** An important feature is that promotion at University is linked to research results. Though this demand may be loose (number and quality of publications required, in-house assessment) and can be circumvented it served as a powerful incentive to practise research in Morocco, Algeria, Tunisia, Jordan and other countries where the public tertiary education is substantial and pre-eminent.

**** Research is part of professional role models***

There are other motivations to do research. They stem from professional models and internalized academic *norms and values*. Young academics and researchers have been

[92] For example, in Jordan, the *Rate of salaries in the public universities* is:

Lecturer	J.D. 600-700
Full Lecturer	J.D. 800-900
Assistant Professor	J.D. 900-1000
Associate Professor	J.D. 1100-1300
Full Professor	J.D. 1400-1600

To be compared with the Average salary of some professions and public careers:

Career	Salary
General Doctor working in the Ministry of Health	400 J.D
School Teacher in a public school	240 J.D
Army officer	400 J.D

[93] However, the Algerian government has just announced they would double the salaries of researchers and increase those of academics in the next months – a much awaited measure.

trained (as doctoral or post doctoral students) within demanding laboratories (often abroad). While spending some time in Diaspora or through cooperative projects, they always remain in contact with international standards. In this process a number of them acquire strict scholarly norms and values.

Moreover, within specific professions (medical practitioners and engineers are well documented cases) research is part of the ***role model***. These professions have respect for the reliability of conscientious and dedicated researchers. Alliances have thus developed between researchers in the public and the private sector (engineers in industry), or between academics and the productive sector[94].

b) Impediments

But impediments are the other side of the coin. Career advantages linked to research achievements are poor, when compared to the financial benefits one may gain from *consulting activities and services* that could be practised instead. In the Centres, research achievements are poorly assessed and not really taken into account for promotion purposes. Moreover, the status of full time researchers is often less attractive than the academics' one.

Researchers and academics in the region are very busy attending multiple occupations other than properly research. This is not necessarily for financial reasons but much more (as we reported in our opening chapter) to gain *status*: for the social environment is not conducive to consider research as a most decent activity. This is why it is difficult to come across "total scientific communities", within which there is a full devotion to the activity.

Struggling with authorities and the academic establishment may also be time consuming. Numerous monographs complain about the strict hierarchy in the Centres, *bureaucracy* and authoritarian control, and the *mandarin* style of academic patronage. Although they are not felt everywhere, these features are called into question in every debate about the weak initiative of young researchers and poor ambition of their projects[95].

c) Brain drain

Some words should be said about **brain drain**. In spite of working conditions which are often better than in other parts of the world, Arab countries are well known for the number of scholars leaving abroad (or students never coming back after obtaining their degree). The main countries hit by an exodus are of course those where the profession is rather poorly treated: Algeria and Egypt. As usual reliable figures are difficult to find on this matter.

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[94] Khelfaoui "Scientific Research in Algeria: Institutionalisation versus Professionnalisation", STS 9 :1, op cit.

[95] See S. Radi and H. Khelfaoui, op. cit.

By 2000 official statistics from NSF (USA) counted 13 000 Egyptian scientists and engineers established in USA, out of whom 5 000 were employed in the R&D sector. This could amount to 35 000 Egyptian highly skilled in S&T established in developing countries[96]. At this moment and for the Near East (in our definition: Lebanon + Jordan + Syria + Palestine + Kuwait for the main origins) the NSF figures were also spectacular[97]. (See Table below).

Number of Scientists and engineers established in USA (born in the Near East). Year 2000

	Egypt	Lebanon	Jordan	Syria	Palestine	Kuwaït	Maghreb
Established in USA	12 500	11 500	4 000	5 000	2 600	2 400	ε
Employed in R&D	4 400	4 900	2 000	1 800	700	1 200	ε
Researchers in the country headcount*	75 000	6 000	6 500		Nd	2 400	40 000
Researchers in the country FTE*	15 000 **	600	750	400 **	Nd	500	8 000

Source NSF, cited in Barré & Meyer (2003). * = ESTIME ; ** STS

According to the NSF, very few scientists from Maghreb were established in USA. But Scientists from Maghreb are heading for Europe (mainly France) and recently for Canada[98]. According to the Algerian trade unions the number of Algerian scientists established abroad had increased from 2 400 in 1984 to 27 500 in 1994; and 90 % of scholarship holders never came back from abroad in 1995. To this should be added the well known exodus of “highly qualified persons” (among whom a number of leading researchers and academics) during the civil war of the 1990s. (Khelfaoui, 2004).[99]

Though the situation is less dramatic in Morocco and Tunisia, brain drain is also noteworthy. Canada and Europe are hunting heads for they need (and will need more and more) scientists and engineers they do not train in sufficient numbers. Neighbouring Mediterranean countries (especially Maghreb with a lot of excellent trainees) are a first rate target.

[96] The ratios come from official Egyptian sources. See S. Radi, Egypt (in *Sciences in Africa*) op. cit.
[97] See Barré & Meyer *Scientific Diasporas*, IRD, 2003, op. cit.
[98] A bibliometric study in social sciences has just proved that 60 % of the 100 most productive social scientists from Algeria were now living and employed abroad (50 % of the 200 most productive, authoring more than 1/3 of the production in the last 25 years). The proportion of Moroccan authors living abroad is 15 % of the 100 most productive (Rossi & Waast, ESTIME, HSS bibliometrics report).
[99] H ; Khelfaoui « Scientific Research in Algeria: Institutionalisation versus Professionalisation, Science Technology & Society, 9:2, 2004 p. 75-101

d) Professionals need new incentives.

The brain drain trend shows that there is a large S&T potential in Arab countries, and a lot of frustrations among them. Old formulas to mobilize capacities have their limits.

Linking academic careers to research achievements has shortcomings. It encourages individual work, rather than more ambitious collective endeavours. And professors who get near or at the highest grade often withdraw from research: if no new recruits enter the system the “engine” jams. This is what is happening (as the enrolment of students is already at a high level, and there is a lesser need for recruiting large troops of teachers).

All in all, motives to persist in research do exist. But much depends on individual choices (and the capacity of some establishments to mobilize them). Though the theoretical potential is large, bibliometric studies show that only a small part of them are really active. There is clearly ***a need for more incentives***. Some establishments (or governments) have tried out various solutions, which are worth reporting as good practices.

One of them consists of *financial rewards*. This may take the shape of a bonus (when participating in a large project, as in Egypt) or a promotion according to merit (as in Morocco, but the gain is weak compared to the possible earnings through consultancy during the same time). It may be a sharing of the benefits earned by the establishment on account of contracts (as in Algeria or in Lebanon). Personal incentives are useful. They are at least a symbolic recognition of the work done while others engage in different businesses.

But many scientists who have a vocation for research are just longing for a normal “laboratory life”. The most convincing encouragements are for them to be linked to *the structuring of research*. This was very obvious in Tunisia, when laboratories were established and continuously supported on condition of their positive assessment. Active researchers joined them, stick to their activity and declare they are satisfied. The same is true in Algeria (though the process is less advanced).

Clearly, there is room for progress in the mobilisation of a larger potential. Without giving up the link of careers to research merit (if better assessed and rewarded) this calls for some new personal incentives and a large share of institution building.

5. Output.

In spite of adverse conditions (underexploited potential, hesitations about the function of research and the support it deserves) *the output is growing*: at least the number of articles published in high-quality international journals. Some salient points are as follows:

a). Production is modest but steadily growing.

The whole zone progressed significantly during the twenty last years. While almost invisible before the 90s[100], it now contributes to *1% of the world production*. This is a modest but meaningful change. The growth was quicker than in the rest of the world –especially the developing world. The movement was not the same in different sub zones.

* Egypt stagnated during the 90s and has regained momentum since 2000.
* Machreq went at a quicker path; but this is especially true in Lebanon and Jordan (which almost doubled their participation in the world science during the last decade)
* The most remarkable feature is *the spectacular growth in Maghreb production*. Within the last fifteen years Morocco more than doubled its participation in articles published by the best international journals (nearly 1 000 participations each year). Algeria did the same in spite of a six years civil war (during which the progression slackened pace but did not collapse). Tunisia shows the most powerful growth. It almost tripled the number of its publications in the last decade, and the growth is accelerating since the new structuring of research (1998 sq).
* On the opposite side, the Gulf countries are stagnating (as well as Saudi Arabia) except for the countries (Emirates and Qatar) which imported foreign campuses. Their scores remain modest (200 to 400 participations per year)[101].

All in all Arab countries have doubled their participation in world science (and increased their world share). They owe it principally to Maghreb countries over the past two decades.

b). A second main feature is the distinctive specialization of this production.

Though they have capabilities in life sciences most countries have a predilection for basic (math, physics, chemistry) and *engineering sciences*. This is particularly true in Egypt (which excels in all sorts of engineering) and Maghreb (Algeria being an extreme case, as shown by its diagram of specialisation in the Regional Report). Machreq countries are more balanced. A remarkable point is that these specialities are strengthening over years.

c). Human and social sciences are active

Generally the production of **human and social sciences** is not well known or visible. There is no consensus on acceptable databases recording their main works (books as well as articles or chapters in collective publications). Fortunately, and for Maghreb only, we could use a bibliometric study realized from the catalogue of a very comprehensive library[102]. Some results are interesting.

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[100] Except for Egypt.

[101] Kuwait experienced a great decline (more than half of its contributing capacity) during the Gulf war and after expulsing a number of highly qualified persons of "hostile nationality". Only since the 2000s years does it come back (almost) to its 1990 level.

[102] ESTIME (2007): Bibliometric study (Maghreb) in human & social sciences.

- The productivity of researchers is neighbouring that of their colleagues in “hard” sciences (an average 2 items each 7 years).
- It is very concentrated: the 15 % most productive authors produce 60 % of the pieces of work, and a small 1% generates 15 % of the corpus.
- There is very little co-authorship. 2/3 of the corpus is written in *Arabic language*.
- The *main disciplines* are literature (and fine arts), law and history. Sociology, economics and political sciences are also important. Other disciplines are much less represented[103]. Psychology is the great missing subject.
- The *main themes* deal with the freeing of the country and resistance attitudes toward colonisation, the cultural features of ancient Arabic civilisation, and questions of identity. Economics treats now of management more than of development strategies. Societal questions like “women”, “democracy” “associations” and violence in “political crises” are gaining momentum while pragmatic topics have carved out their place (urban problems, agriculture, education and all sorts of juridical issues).
- There are some variations among the countries but a great similarity of concerns and moves. The main difference is rather between disciplines which are nomothetic (they seek social “laws”: economics, sociology, linguistics…) and others which are more descriptive or topical (philosophy, history, arts & literature…). They have distinctive themes and a specific relation to language[104].

In Machreq and the Gulf the situation may be different. Arts and Humanities have the largest space. They enjoy public interest and they have ample sponsorship. Social sciences are less popular; but they are pragmatic, their best scholars are often called as experts or consultants by authorities, a number of teams practise action research and there is an international market for their studies and work (especially in Machreq).

d). Finally, what are the links of research with society?

It is clear that arts and humanities have an audience (through the media and many students) and a large sponsorship. Social sciences have their own (they often teach in different Faculties and they are more committed to private consultancies). What about natural and exact sciences? They are less readily understandable by a great public and their “would-be” sponsors (the economic sector) often claim they do not fit their needs.

It’s true that very few patents come out of Universities. But links with industry go through other ways: continuing education, technical services and consultancies. An assessment of the S&T system in Morocco has recently shown that there are many more collaborations

[103] Though influent like islamology and *philosophy* or proportionally well developed – as linguistics.
[104] Nomothetic disciplines need to enter debate all over the world: they write in European languages. Topical disciplines speak rather local languages (here: Arabic).

than had been expected[105]. Most of them remain informal. They result from scattered and individual initiatives. They involve specifically Engineering "Schools" (more visible than the University labs, which are often under-equipped and badly marketed by their own establishments). And they concern a fringe of innovative firms: their characteristics have just been well documented by several "innovation" or "S&T potential" studies in Jordan, Tunisia and Morocco[106].

Conventional views of academics and businessmen remain those of mutual incomprehension. But beyond official words practical experience may be different. Opinions of "executives" were interesting to pick out (See the regional Report). The result is a very good *world ranking* of several countries with regard to the availability of scientists and engineers, local research & training services, the quality of scientific institutions and University-industry collaboration. Tunisia is excellent for all these issues (and several other related indicators). Emirates and often Qatar are very good. Morocco and Jordan have good or very good rankings. Algeria, Egypt and Syria have weak points (mostly for services and collaborations).

6. Conclusion

The Arab countries have by now an important S&T potential, little tapped for research. Consequently brain drain takes a heavy toll: a few years ago, there were as many Egyptian scientists employed in R&D through the world as there were (FTE) in their own country; and twice to four times more regarding Machreq countries[107].

There would probably be much to gain if the *function of research* were recognised and considered as a lever for development. Research (which by now is a subordinate function in different types of establishments, or an investment and a hobby for a few volunteers) could then be taken seriously (for itself, with its own goals and system). Its ambitions could become greater and its relations with society clearer and more efficient.

Scientific and technological production (which grew much during the last 2 decades) finally relies on a small number of performers (a few research universities plus – in Egypt and Maghreb – some Centres and Polytechnics); and on a small number of researchers in each of them (working often on an individual basis, or within small teams and short networks). Old mainsprings of this activity (like professional values, and linking the career of academics to some research achievements) are diminishing; and there is a need for institution building and new incentives. Good practices have been described. The most efficient one seems to

[105] See Kleiche et al. *Le maroc scientifique*, op. cit.
[106] See the ESTIME project.
[107] There are no reliable figures for Maghreb countries, but brain drain costs them dear: especially in Algeria, where the profession is ill treated. According to NSF (2000), Kuwait was much hit but not other countries from the Gulf.

be the structuring of research through strictly assessed laboratories and research units (as in Tunisia[108]).

There is a responsibility for foreign agencies (already active) to contribute to this upgrading: at least by supporting specific laboratories for longer periods of time and helping them to enter into intensive networking or/and large programmes with serious technological stakes.

We cannot end this report without stressing that there is a need for accurate data and follow up studies in the region.

> Some countries already realized inventories of their scientific potential. Some organized the assessment of their S&T system (Morocco). These concerns are clearly gaining ground, even where we had difficulties to find relevant information about the current status of research (Egypt, Gulf countries).

Beyond that is the need for updating such data. Tunisia has just launched its "Observatory of S&T", and Lebanon prepares for that. Others are considering it (Jordan, Morocco). As all the countries are different (science goals and policy, governance and supervision, performers) each of them needs to put a specific service in charge of gathering reliable and consistent data.

The next (parallel) step would be to promote a regional Observatory (and at first a *network* of the ongoing ones) that could help in standardizing and validating the data (as RECYT does for Latin America), analyzing them and launching specific studies (e.g. a benchmarking of good practices). It could also support capacity building. It seems that such a proposal is timely: it could meet approval and gain sponsorship in the region.

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[108] This implies that such units receive long standing support, and gain access to up to date equipment and documentation.

3.3 ASIA REPORT

Our review of Asian countries produced 10 country reports: Bangladesh, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam. [109]

Although these countries were selected because they met the criteria (developing countries and not well-researched) for inclusion in this review, there are still significant differences in their science and technology systems. These differences are due to many factors: socio-political histories, geography, political and economic (in)stability, different legacies of colonial science influence and subsequent science institutionalization development and so on.

One example of the differences between the seventeen countries is illustrated by differences in scientific output as measured by articles published in the ISI-indexes. In terms of this measure, one would distinguish between three clusters of countries: those countries (Singapore) that produced more than 2000 publications between 2001 and 2004 (Tijssen, 2006); another cluster of countries (Malaysian and Pakistan) who produced at least 500 publications and then the remaining countries who produced less than 500 or – stated differently- less than 100 articles on average per year.

Our summary of the country reports in this region is organized according to 5 themes.

A. Recent trends in governance and policy development in S&T

The review of science policy development paths in the individual ten countries included in this regional report suggests at least three "clusters" countries with different trajectories.

- A first cluster of three countries – Singapore, Malaysia and Thailand – where science and technology policies developed more as the result of industrialization policies and plans (this is especially true of Singapore and Malaysia).
- A second cluster of countries where science and technology goals and priorities were subsumed in more general macro-economic plans that were centrally driven (Indonesia, Philippines and in the socialist Republic of Vietnam)
- A third cluster of the poorer countries in our review – Bangladesh, Nepal, Pakistan and Sri Lanka – who were early developers of formal science and technology policy documents (very soon after independence) but where investment in R&D is also of the lowest.

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[109] This regional report is based on the individual country reviews contained in the Asia compilation as well as some additional references. The authorship(s) of the individual countries in the Asia compilation are clearly identified and acknowledged in the compiled report. In summary, therefore, I only list here the individual authors of the country reviews: VV Krishna, Usha Krishna, S.T.K. Naim and Seetha Wickremasinghe.

It is important to emphasize that this threefold classification generates rather "loose" clusters only with regard to science policy development. The research systems of the countries in the same cluster differ from each other in significant ways which are discussed below.

Trajectory 1: Science policy development dominated by industrialization policy

Singapore: Singapore became independent from Malaysia on the 9th of August 1965. In the 1960s import substituting industrialization was replaced with rapid industrialization through attracting foreign investment for export oriented and labour intensive manufacturing. The export-led industrialization strategy was supplemented by moves to develop Singapore into a regional and international financial centre. Foreign exchange controls were removed and various financial incentives introduced. S&T was first identified as a priority in 1968 when the Ministry of Science and Technology was established to promote the role of science and technology in the education system and the economy. In 1967, the Singapore Science Council was established as an advisory body on work force training and R & D in industry. Early in 1991, the Government set up the National Science and Technology Board. This Board produced in August 1991 the National Technology Plan 1991 outlining a comprehensive and coordinated national strategy for R & D for the next 5 years. The plan emphasized the role of R & D in providing industrial competitiveness.

The success story of Singapore is by now well documented. One indicator of its success in becoming an industrially competitive economy is R&D intensity (as measured by Government Expenditure on R&D [GERD] as proportion of Gross Domestic Product [GDP). In 2004, expenditure on R&D was $4,062 million, which constituted 2.25% of gross domestic product (GDP) and one of the highest in the world. The contribution of private sector to R&D is noteworthy as they contributed 64% ($2,590 million) of total expenditure on R&D and amounted to 1.43% of GDP, in 2004. The government sector was 11%; higher education sector 10% and the public research institutes 15% of total expenditure on R&D. Private sector expenditure on R&D increased 24% from $2,081 million in 2003 to $2,590 million in 2004. As a percentage of gross domestic product (GDP), private sector expenditure on R&D increased from 0.46%% in 1990 to 1.43% in 2004 trebling in 14 years.

Malaysia: Malaysia transformed from a country dependent on the production and export of primary commodities to an emerging multi-sector economy over the period from 1971 through the late 1990s. During the last decade, the country emerged as a leading exporter of high technology products. Its recent growth is almost exclusively driven by exports - particularly of electronics, followed by palm oil and palm oil based products and other manufactured goods and articles. The services sector contributes 57% of the gross domestic product (GDP), manufacturing constitutes 30% of GDP, while a lesser amount is contributed by the traditional sectors of agriculture and forestry (8.4% of GDP) and, mining and quarrying (7.2% of GDP).

Malaysia's S&T development has thus far been based on its S&T Policy which was adopted in 1986. The tenets of this policy were implemented through the National Plan of Action for Industrial Technology Development (1990). The S&T policy went through a review process in the year 2000, and this resulted in the formulation of the Second National Science and Technology Policy (STP II), which was launched in the year 2003. The Institute for Management Development (IMD) in its 2004 World Competitiveness Yearbook ranked Malaysia as the fifth most competitive country in the world (for countries with a population of greater than 20 million). It is perhaps then not surprising that investment in R&D has been fore grounded and increasingly so: from 0.37% in 1992 to 0.69% in 2002. It is also noteworthy that 65% of R&D in 2004 was funded by the private sector.

Thailand: Although not in the same league as Singapore or Malaysia, the more recent economic policies of Thailand have included an emphasis on S&T. S&T initially did not receive much attention in the national development plans until about the Fourth Plan. It was only in Fifth Plan (1982-86) that the government had a chapter on S&T for development. What is further of interest is its adoption of the concept of national innovation systems and industrial clusters in the most recent ten-year Science and Technology Action Plan (2004-2013**)**. The main objectives of the plan are to enhance Thailand's capabilities in response to rapid changes in the age of globalization and to strengthen the country's long-term competitiveness.

Gross expenditure on R&D (GERD) as proportion of GDP increased from 0.21% in 1987 to about 0.26% in 2002 which is quite low compared to neighbouring dynamic economies of Asia, namely, South Korea, Taiwan, Singapore and even Malaysia.

Trajectory 2: Science and technology subsumed in (central) macro-economic planning

Central economic planning is most closely and obviously linked to socialist regimes. This is certainly the case in Vietnam in our review. However, although not explicitly socialist, the governments of Indonesia and the Philippines also followed over the recent past very rigorous central economic planning as expressed in 5-yearly plans. Within these frameworks, S&T were always seen as secondary (and even derivative?) to economic priorities rather – as more recent studies would suggest – as the driver of economic growth and wealth creation.

Indonesia - In the 'Constitution 1945 of Republic of Indonesia' chapter 31 assigned an important role for S&T in the development of the country. From 1950, Indonesia started its programme of expanding education at all levels and science and technology. In 1956, the government formed the Indonesian Council of Sciences to coordinate developments in S&T and to advise the government on science and technology policy. What is noteworthy about the "development" of science and technology in Indonesia is that it formed part, until recently of the Government's macro economic development plans. The first such five-year plan (PELITA I) commenced in 1969 and concluded in 1974. Science and technology activities during PELITA III (1979-80 to 1983-84) were grouped into pure and applied sciences, supporting each other and directed towards the requirements of short-and long-term developments. The fifth Five Year Development Plan (PELITA V) laid down the task for the National Research Council to prepare the formulation of the principal National Programme in the fields of research and technology through planning and national development strategy.

Philippines: Agenda setting for S&T in the Philippines is embodied in successive S&T development plans through the years. There was the S&T Master Plan 1990-2000 (STMP) developed during the regime of President Aquino; the Science and Technology Agenda for National Development (STAND) 1993-1998 developed in 1993; the DOST Medium-Term Plan (MTP) 1999-2004, which was actually only a departmental plan; and the recent National Science and Technology Plan 2002-2020 (NSTP).

What is disappointing about S&T in the Philippines is that despite the inclusion of S&T in the five-yearly development plans, expenditure on R&D has been declining systematically from 1992 (0.2%) to 2002 (0.1%). This has been accompanied by a similar decline in the number of research workers in the system: from 15 600 in 1992 to 8 700 in 2002. The biggest decline occurred in the government sector. In addition nearly 60% of government expenditure (2002) was devoted to agricultural and industrial production and technology while about 14% was spent on environment and human health. It is clear that agriculture constitutes a considerable proportion of the R&D budget. In Philippines, the agriculture sector has a well-developed R&D system relative to the other sectors because the government recognizes the public nature of agricultural R&D.

Vietnam: As early as in the late 1950s, a national agency for S&T was established to coordinate and promote S&T. During the 1960s and 1970s, even at the height of the American War, a large number of scientists and engineers were educated in socialist countries and numerous R&D institutes and universities were created by the government.

After the liberation in 1975, the country embarked on building S&T institutions and organized science and technology drawing inspiration from the Soviet Union. S&T was seen as a vital part of a largely self-contained, self-sufficient economic development model. The number of government R&D institutes and centres mushroomed in the period up to the late 1980s. Since the adoption of the *doi moi* (renovation) policy in 1986, far-reaching changes have been taking place. The state budget is no longer the only source of funds for R&D, and more and more funds are coming from industry and other sources.

More recent trends in Vietnam have been towards greater liberalization of higher education and science. The government no longer administers and controls all the R&D organizations and universities, and many collective and private R&D organizations are now in operation.

Trajectory 3: Early developers (adopters?) of science policy but low investment in R&D

The four countries included in this cluster all initiated the development of their first S&T policy documents as well as putting in place the first formal governance structures for S&T soon after achieving independence. But these countries also share one other common feature: at the time of independence none of these countries necessarily had a rich legacy or well-established S&T infrastructure in place – despite some efforts in this regard under former colonial rule. It is perhaps fair to say that whereas colonial science in other parts of the world (e.g. Australia or India) led to the establishment of notable scientific institutions, this was not the case in these countries.

Bangladesh The area that is now Bangladesh was part of the old Bengal Province of India under British rule and most of the S&T infrastructure and R&D institutions were located in and around Calcutta, the capital of the province. As our country review shows, the only research station inherited in 1947, when British rule ended and the country was partitioned, was an agriculture research institute specializing in rice research. After independence in 1971, Bangladesh found itself in a difficult economic situation with a weak R&D infrastructure. The country was forced to build new R&D institutions and technical universities. The National Council for Science and Technology (NCST), created in 1983, is the main apex body for science and technology at the highest level for policy-making on S&T in the country. It worked for three years to draft a S&T policy, which was formally approved by the government in 1986.

Sri Lanka: According to the country review, the period following independence, saw a form of ‘colonial legacy’ which continued in Sri Lanka and which paid little attention to the development of an indigenous science and technology base. One of these colonial institutions, the Ceylon Association for the Advancement of Science (CAAS), the predecessor of the Sri Lanka Association for the Advancement of Science (SLAAS), voiced its opinions about the professionalisation of science and developing local scientific institutions as early as 1944. After independence in 1948 a notable science policy initiative from CAAS in 1950s was its submission of a memorandum to the government for the establishment of National Research Council to foster scientific and industrial research. It was mainly because of the CAAS efforts that the government set up the Ceylon Institute of Scientific and Industrial Research (CISIR) in the 1950s. Exploring the historical growth of

S&T policies reveals that even though the country established a number of R&D institutions after independence in 1948, there was no formal S&T policy or document from the government until about late 1960s.

Nepal: The beginning of national S&T policies in Nepal can be traced to the early 1960s. The country report indicates how the government sought the assistance of UNESCO to advise on the formation of a body for the formulation of a Science Policy. In 1966, a detailed survey of scientific infrastructure was prepared under the commission of UNESCO – perhaps one of the earliest efforts of this nature? The Second General Assembly of the National Commission for UNESCO held in 1966 for the first time recommended long-term science planning on a national scale. During the assembly, the Science and Technology Sub- Committee also proposed the establishment of National Council for Scientific Research for the co-ordination and implementation of scientific research activities (NNC/UNESCO 1966). The recommendations also emphasized that the scientific capabilities of the university sector be strengthened. A series of meetings between government institutions concerned with science and UNESCO led to the institutionalization of science policy mechanisms and the establishment of the National Council for Science and Technology (NCST). The main objective of the NCST was to formulate a national Science and Technology policy. The council contributed to the formulation of the first Science and Technology policy that was mentioned for the first time in the Sixth Five Year Development Plan (1980-1985).

Pakistan: Pakistan's independence and partition from India did not result in a positive outlook for science and higher education. Pakistan inherited only four of forty laboratories established in pre-partition India. Out of 20 universities, only one fell into the territory of Pakistan. Soon after the inception of Pakistan, the government recognized the importance of science and technology and established a number of R&D organizations. Simultaneously a number of colleges and universities were established to increase the number of R&D personnel. The potential of agriculture was also realized and great emphasis was laid on the development of agriculture related R&D organizations. The Ministry of Agriculture established the Central Cotton Committee in 1948 followed by the Food and Agriculture Council in 1949. The Council of Scientific and Industrial Research was established in 1949 as an attached department of the Ministry of Industries. This Council was made autonomous and renamed the Pakistan Council for Scientific and Industrial Research (PCSIR) in 1953. It has since established 16 laboratories in major cities of Pakistan. The Pakistan Medical Research Council was also established in 1953 and the Atomic Energy Research Council in 1956. While the initial phase of institutionalization of science and technology continued in the late 1940s and 1950s, the formal formulation of policies for science and technology would only commence in the 1960s

B. Contemporary institutional landscape

Given the pervasive colonialism that characterized the majority of countries in our review (with the exception of Thailand, the other nine countries were at different periods in their history under Spanish, Portuguese, Dutch, American, Japanese and British rule!) it would be surprising if some form of colonial influence is not visible in the institutions of science in these countries.

Political instability, especially in the form of prolonged wars (as in Vietnam) or for shorter periods in Indonesia and Sri Lanka, generally is detrimental to the flourishing of science and research in a country. But political stability is, of course, not synonymous with democratic governments. In many of the countries under review, political stability was established under dictator and/or one-party political systems.

We indicate how some of these themes are manifested in the individual countries reviewed.

Bangladesh: Lasting colonial legacy: The influence of British rule in India, Pakistan and Bangladesh is clearly illustrated in the adoption of the British CSIR model in Bangladesh. The major activities that could lead to viable outputs for industrial technology development are concentrated in the Bangladesh Council of Scientific and Industrial Research (BCSIR). The BCSIR is the only government-sponsored industrial research organisation with the mandate to play a crucial role in the country's industrial development. The BCSIR has a total staff of around of about 1200, out of which one-third are scientists and technologists in the year 2003.

Indonesia: Dependency and late institution building

The first organized scientific activities in Indonesia started in 1778 under Dutch rule with the founding of the “Batavia Society of Arts and Sciences”, a private organization for the promotion of research for the benefit of trade and agricultural development. Our country review points out that although the work of its members initially covered all fields of science, their interest gradually shifted more and more to the social sciences. Even to the present period, the “Proceedings” of the Batavia Society of Arts and Sciences remain an important source of knowledge concerning the social and cultural life of the people in several parts of the Indonesian Archipelago. The establishment of the famous Botanical Garden in Borgor in 1817 was the starting point of systematic botanical research. Gradually more and more research activities were carried out in other fields such as zoology, geology and marine sciences. But during Dutch rule, most scientific research was undertaken by Dutch scientists with little indigenous scientific capacity being built. It was only after independence in 1945 that this trend was reversed.

The legacy of long-standing Dutch support for science and technology in Indonesia – that goes back to the late eighteenth century – thus did not translate in the development of local institutional capacity in S&T in Indonesia. It is only after independence in 1949 that one witnesses large scale growth in the number of higher education institutions as well as in the number of government-funded R&D performing institutes – especially in the field of agriculture.

Although Indonesia has a number of "flagship" institutions in strategic areas such as Atomic Energy and Aerospace research, the establishment of such institutes is not indicative of high R&D intensity. In fact, compared to countries such as Singapore, investment in R&D remains very low staying around 0.2%. This probably also explain the role and influence of a rather large number of international research agencies in Indonesia – especially again in the field of agriculture.

Building on the colonial legacy: The case of Nepal

Various scientific institutions were established in Nepal under British rule: the Agriculture Office, in 1924; the Civil Medical School for "Compounders" and Dressers in 1934; Technical Training School for Sub-Overseers in 1942); and the Forest Training Centre for Rangers in 1942. The first College imparting science was begun in 1919. On gaining its independence in 1950, Nepal embarked on the path of modernization. Following the development plan of 1956, the Nepal Government also took the initiative to develop infrastructure for S&T activities.

The departments of Irrigation, Hydrology and Meteorology, Mines and Geology, Survey and Medicinal Plants were among the first government S&T institutions to be established in Nepal. Many of these institutions were established within the Ministry of Forestry. The Ministry has promoted the establishment of some other pioneering organizations such as the Royal Drugs Research Laboratories, Royal Drugs Limited, the National Herbarium and Plant Tissue Culture Laboratory, the Forest Research and Survey Centre, the Central Food Research Laboratory, the Herbs Processing and Production Limited and the Department of Drug Administration. The continuing British influence is evident in the names of some of these laboratories.

Political instability and the challenge of building scientific institutions: Sri Lanka

Over the last decade, the weakening economic situation, compounded with ongoing civil conflict, has had a telling impact on Sri Lanka's S&T. This is best illustrated by the stagnation in R&D expenditure over the last few years. In real terms the GERD to GDP ratio witnessed a sharp decline from 0.30 in 1966 to 0.19 in 2000. The impact of these low levels of R&D investment has also had a debilitating effect on human capital in S&T. The available records from various sources show that the number of scientists in the R&D

institutions had increased almost nine fold from 204 in 1984 to 1972 in 1996 but has decreased to 685 in 2000. As the R&D Survey (2000) of the NSF indicates, R&D institutes accounted for only 13% of the total scientific human resources while the rest is accounted by the universities. Further, as our country review shows, there has been either relative stagnation or only marginal increase in the endowment of scientific human resources in most of the R&D institutes between 1998 and 2004. For instance in ITI, the country's main industrial research laboratory, the institute employed a total of 329 personnel out of which only 21% (69) were scientists and engineers in 1998 which decreased to 67 in 2004 (see ITI 1998). Another major R&D institute of Sri Lanka - the National Engineering Research and Development Centre (NERDC) -also suffered with low level of human resources during the last decade even though there has been a marginal increase between 1998 and 2004 from 39 to 47.

No colonial legacy: Thailand

In Asia, unlike other countries, Thailand was not under colonial rule. With origins in Chinese culture, Thailand adopted Brahmanic system of justice and Therevada Buddhism as its state religion. The history of modern science in Thailand can be traced to the ascendance to throne of King Mongkut of Chakri dynasty in 1851; and his successor King Chulalongkorn. The latter was the first King to travel to European countries and the first to send royal family members and others to study and draw western educational experiences from Europe. He founded the first Thai university, Chulalongkorn University in 1916. However, the first modern science related institutions were established in the late 19th Century beginning with Paetyakorn Medical School in 1889; Law School in 1897; Royal Pages School for administrators in 1902 on the lines of the French Grandes Ecoles . The European influence continued into the 20th Century, mainly from 1940s when the country embarked on building modern higher educational and S&T institutions.

The influence of the Soviet academy of science model: Vietnam

One of the key features of former socialist regimes in central and Eastern Europe and the former Soviet Union, was the prominence accorded to the prestigious and well-resourced Academies of Science. This is certainly still the case in Vietnam. Among all scientific and engineering organizations, the Vietnam Academy of Science and Technology is the largest one. The institute has 18 research institutes and 9 regional branches in various fields of science and engineering. Their affiliates are located in all parts of Vietnam with concentrations in Hanoi and Ho Chi Minh City. The institute set up 16 enterprises; 21 scientific centres (under 35 Degree); 16 higher education institutions; 7 administrative bodies and 11 journals/magazines. By the end of 2003, this institute had a staff of about 3000 people.

C. The role of the universities in public R&D

Very limited to negligible contribution

Bangladesh is an example of a science system where little research is being done at the universities. Research there is funded through the University Grants Commission but given low levels of government support for R&D these funds are quite limited and have not increased over recent years. It seems that public R&D in Bangladesh is confined mostly to government organizations (BCSIR and ARC) with little support for university-based research.

Nepal: Besides some departments at the science faculty of Tribhuban University, there are 4 institutes which conduct research: Institute of Agriculture and Animal Science, Institute of Engineering, Institute of Forestry and Institute of Medicine. Research Centre for Applied Science and Technology (RECAST). Research activities are also carried in other universities such as Kathmandu University, Purbanchal University and Pokhara University. However, much of the research carried out in the university sector mainly relates to higher education research at the masters level and only occasionally medium term R&D projects are undertaken.

Expanding but limited HE sector

Higher education in Indonesia began at the end of the Nineteenth Century with the establishment of medical education for local doctors in Jakarta. As our country report shows, after independence in 1949 and in particular after promulgation of the Education Act of 1961, the country witnessed significant progress in higher education. In 1950, there were 10 institutions of higher education with 6500 students. By 1970, there were 450 private and state funded institutions of higher learning with enrolments of 237,000 students. This increased further to 900 institutions in 1990 with nearly 1.5 million students.

Pakistan

Pakistan is another example where R&D in the Higher Education sector is very limited. Despite the fact that there are 37 public universities, only the Quaid-e-Azam University of Islamabad, nine centres of excellences and some institutes were involved in postgraduate research. This is not surprising if one keeps in mind that only 30% of staff in these universities have PhD degrees. The Universities Grants Commission was reconstituted as the Higher Education Commission (HEC) with the mission of introducing quality in teaching, research, management and governance of universities. HEC has also launched programmes to increase PhD-level work force from the present 2800 to 8000 over the next 5 years. Each year about 250 PhD students are sent to universities in Germany, France, Austria and China. To encourage quality research, emoluments of scientists and engineers working in the public sector universities and R&D organizations have been substantially increased by linking their research performance to a Research Productivity Allowance (RPA) and Special Science & Technology Allowance. Tenure track system of appointments has been introduced in universities to increase the salaries of faculty and link it to performance. These steps are designed to introduce quality in teaching, promotion of research and to reduce brain drain.

D. Current state of human and infrastructural resources

Individual countries have responded in different ways to human resource challenges in the field of S&T. We discuss briefly three examples: Malaysia, Pakistan and Singapore.

Human resources in S&T development lagging behind economic and industrial growth: The case of Malaysia.

The number of researchers in Malaysia stands at 18 researchers per 10,000 workforce (2002). This figure seems low when compared with that of developed countries, which average 80 researchers per 10,000 labour force. Although Malaysia fares better when compared with some of its Asian neighbours, Thailand, Philippines and Indonesia, our country review nevertheless argues that there are indications that Malaysia does face shortages of skills and capabilities in some areas. This is likely to be a constraint for Malaysia to develop a strong technology base. In cognisance of this shortfall, various initiatives have been made to continuously develop Malaysia's human resources, through provision of better access to training and re-training of human resources. On a similar note, the Government has also sought to improve programs to attract qualified personnel from abroad through its 'Brain Gain' programme.

Innovative and successful strategies for human resource development

Pakistan

An example of an innovative initiative to fast-track the development of highly skilled workers is discussed in the country review of Pakistan where the Ministry of Science and Technology in 1985 launched a Human Resource Development Program. Over 1000 young scientists and engineers were sent abroad for higher studies. The cost of this programme was US$70 million. In order to promote indigenous technological development, the government established the Scientific and Technological Development Corporation (STEDEC) with US$ 1.16 million as seed capital to commercialize processes and products developed by R&D institutions. In addition, to promote research, the government established a Research and Development Fund. Scientists, engineers and technologists were awarded research allowance, computer allowance and PhD allowance in addition to the normal pay scales. In the Seventh Five Year Plan (1988-93), there was considerable enhancement of funds for S&T (US$522.26 million against US$430.89 million in the Sixth Five Year Plan (Government of Pakistan. 1982 and 1987).

Singapore

The Singapore case is a very good example of how a small Island country without any great natural resource endowments of the primary sector has industrialized over the last four decades through the development of technological capabilities in the manufacturing sectors of economy up to 1980s. Once the country begun to experience success through the application of knowledge, the government policies led to two major strategies of mobilizing intellectual capital by supporting higher educational institutions including public research institutions; and secondly by mobilizing global companies to invest in R&D and technology development and commercialization in Singapore since early 1990s. As these two strategies paid off by the late 1990s, the country further raised the level of science and engineering and management support through three major universities and their research centres to embark on science based innovation by targeting two major areas, namely biomedical engineering and information and communication technologies including telecommunications.

In 2004, there were a total of 18,935 research scientists and engineers (RSEs) and 3,705 fulltime postgraduate research students (FPGRSs) at the master degree and PhD levels. The country review report identifies as the unique feature of human resources of Singapore the way they identify researchers in R&D and the specific identification of engineers which they call research scientists and engineers. This illustrates the importance given to engineering and technology sciences compared to other countries in the Asian region.

E. Informal S&T structures and scientific communities

Informal S&T structures can flourish – or at least survive – in the smallest science systems. Nepal is a case in point. It has 74 professional societies, which are registered with the different District Administrations. The membership of the professional societies existing in Nepal is quite low; the majority of them have less than 500 members. By membership, the largest one is the Nepal Engineers Association and the Nepal Medical Association, which have memberships of 3578 and 2146, respectively. As far as journals are concerned, the country review shows that there are 37 local journals. These journals are published by various professional associations and specialized journals cover a specific discipline. Journals such as the *Journal of the Institute of Science and Technology*, Tribhuvan University and the *Nepal Journal of Science and Technology* launched by RONAST and Scientific World published by Ministry of Science and Technology publish articles from all disciplines of S&T. In terms of publications, Nepal is yet to register its presence at the international level. Much of its science publication output finds its way into its annual professional societies and journal established by these societies.

Pakistan

At the other end of the spectrum, one finds Pakistan which currently boasts 315 scientific journals and 24 scientific societies.

F. Knowledge production and *output*

We conclude this report with a comparative glance at the research output of the countries included in our review (excluding Nepal). The salient points that emerge from comparative statistics available are the following:

- With the exception of Singapore annual production of ISI articles is weak to neglible. On the lower end, the performance" of countries such as Bangladesh, Indonesia, the Philippines, Sri Lanka and Vietnam is both surprising and of concern. Although one should allow for the possible constraining effect that publication in mostly English journals might have, it is quite obvious that these countries are not doing enough to incentivize and support (basic) research at their universities.
- A more positive finding is evidenced by the steady increase in output in all countries under review. The smallest growth is documented for Indonesia, Pakistan and the Philippines. The most spectacular growth was recorded for China, Korea, Singapore and Thailand.

Concluding comments

- The ten countries in our review exhibit huge variation in S&T priorities and associated emphases in investment: From the agriculture and resource-based economy of Bangladesh (where investment in agricultural R&D predominates) to the manufacturing and high-technology industrialized economies of Singapore (and to a lesser extent Malaysia and Thailand).
- Very different science governance models: From the (socialist) model of central planning as evident in the heyday of Suharto's rule in Indonesia and still current in Vietnam (where the main institutions are modeled along the lines of the old Soviet Academy of Sciences) to the much more "liberal" approach associated with national systems of innovation models in Thailand and Singapore.
- The emphasis on and support given to the social sciences in these different science systems vary hugely. In the Vietnamese case, social science is afforded a central role (but within the constraints of a socialist model). In countries such as Singapore with its huge emphasis on SET, the social sciences are nearly invisible. This is also the case, but for very different reasons, in countries such as Bangladesh (dominated by agricultural R&D) and the Philippines (where the science system is generally in decline or at best in stagnation).
- The presence or absence of colonial rule (mainly British or Dutch) has influenced the state and strength of science in different countries differently. Although science in Indonesia has a long and rich history through early Dutch efforts, all of these were

established and geared towards Dutch interests. Worse, local scientific facilities such as the famous botanical gardens at Borgor were used by Dutch scientists exclusively. No indigenous scientific capacity was developed with the result that with independence in the 1950s the country had to start anew with developing its own institutions and capacities in science. The British model of science, and especially the concept of a central council for scientific and industrial research (CSIR) was hugely influential in India (not included in our review) and hence also in Pakistan and Bangladesh.

- Some of the countries in our review have witnessed a fair degree of political instability over the past 50 years which in turn has had very negative impact on the science systems in those countries. Some of these related to lengthy periods of war (Vietnam) or civil war (Sri Lanka); others to significant regime changes (Suharto in Indonesia and more recently Musharraf in Pakistan).
- Two countries in our review stand out as examples of extraordinary industrial and economic growth: Malaysia and Singapore. Malaysia went the route of liberalizing its economy and encouraging foreign direct investment as much as possible. This has paid of and its sustained economic growth has led to a situation where it is now regarded as one of the most competitive countries in the world. However, its expenditure on R&D as percentage of GDP remains below 1% and although it has given increased attention to the fields of SET, its graduate output is still dominated by the SSH. All of this has created a situation where human resource development has become its biggest constraint and also challenge. Singapore, on the other hand, has converted its huge economic growth into substantive investments in R&D including in human resource development. Its most recent GERD/GDP of 2.6% is significantly above the EU average. As far as scientific field is concerned, there are huge investments in life sciences (microbiology/ stem cell research, human genomics and bioinformatics but practically nothing in the social sciences.
- Knowledge production as measured in terms of article output in ISI Web of Science is generally poor in our ten countries. Except for Singapore (which now produces more than 5000 articles per year in ISI journals), the output of the other countries (relative to their size) remain small (Pakistan, Malaysia and Thailand) to nearly insignificant (Bangladesh, Nepal and Sri Lanka). There is some evidence of a culture of privileging local journal support, especially in Pakistan and Nepal.
- The role of universities in knowledge production is equally variable. Not surprisingly some universities in Singapore (such as the National University of Singapore) have achieved international recognition. This is also true of some institutes in certain countries (e.g. in Pakistan – The Hussein Ebrahim Jamal (HEJ) Research Institute of Chemistry was established at the Karachi University). In most countries in our review, however, research at universities is limited mainly because of a lack of

sustained investment in R&D and small numbers of post-graduate students which in turn is linked to the small proportion of staff with doctoral degrees themselves. This situation is found both in highly industrialized countries such as Malaysia and increasingly Thailand as well as in countries such as Nepal, the Philippines and Sri Lanka. It is, therefore, not surprising that the development of highly skilled human resources remains the single biggest challenge for many of these countries.

- Within the domain of S&T policy development, interesting differences have been documented. In most countries in our review, systematic attention to the development of a national science and technology policy document only commenced after independence and usually only in the 1970s and 1980s. In the Singapore and Malaysia cases, science and technology policy development was intimately linked to industrial policy development. To some extent this is also the case, somewhat later, for Thailand who has adopted the notion of a national system of innovation in its own science policy development process. Other countries with a much clearer socialist economic legacy – such as Vietnam and Indonesia (and Pakistan under Bhutto) – incorporated science and technology policy issues within the framework of centralist economic planning. This usually meant that S&T was only fore grounded in the 1980s within the 3rd or 4th cycles of economic planning.

3.4 LATIN AMERICA AND CARIBBEAN REPORT

This Report draws mainly from the excellent monographs prepared by **D. Villavicencio *and his team*** (See their compilation in a special volume). They concern the 13 following countries:

Argentina, Bolivia, Chile, Colombia, Costa Rica, Cuba, Ecuador, Jamaica, Mexico, Panama, Peru, Trinidad & Tobago, Venezuela

We supplemented their information by an intense reading of articles dealing with S&T and R&D in Latin America; and with indicators published by the regional Observatory of S&T "RECYT". Latin America provides this excellent opportunity, for it is the Continent where studies on science are the most developed, ancient and institutionalized in the developing world[110].

We shall confine here ourselves to a general view and summary findings.

1. Salient traits of the Region

Latin America is specific in several ways. These features have an impact on the dynamics of S&T in the continent.

1) Colonial rule is an old story, and did not leave any scientific legacy. This is a clear difference compared with Africa and most parts of Asia. Modern science developed « indigeneously », and coincided with ***a long process of education*** (including tertiary education, at the latest by the end of the 19th century).
2) The carving of a « space for science » from the beginning is rather a story of *key figures and Research Centres* (Museums, Observatories, Institutes and Foundations, often staying aside from the regular institutions). The first circles of devotees enlarged and aggregated new converts among the professional staff of Universities and State Agencies. The whole movement culminated in the emergence of ***scientific communities***, which developed their own powerful organisations: Associations for the Advancement of Science (in the 1930s-1950s), national and even continental learned Societies or establishments. These institutions are autonomous and claim the loyalty of researchers independently of the service they are attached to.
3) ***Later,*** government frameworks were adopted in most countries (by the 1960s), with a *very similar and original pattern: that of* ***National Councils*** *for Science* (CONA or CONICYT…) which are autonomous bodies in charge of administering national budgets, elaborating a policy and planning the development of S&T. They are under

[110] For a general view, see P. Kreimer "Present trends of the studies on science in Latin America" *Science, Technology & Society*, 10 (2), 2007

the disputed control of the scientific community (which was at their origin) and the State (which provides them with funding). Supported by the former, they have survived many stormy and bloody changes of regime, as well as the twists and turns of economic policies[111]. They have been maintained as supervisors and drivers of Science for decades, and their similarity favoured their relations, networking, benchmarking, exchange of ideas, persons and good practices, and professionalization. As a result, one can say that there is an implicit *Latino American space for science*, with specialists (often economists of science), Continental institutions (Universities, Research Centres, Observatories) and an intense circulation of scientists and ideas. This is much more the case than in any other part of the developing world.

Nevertheless there is room for ***important discrepancies*** of the S&T systems, linked to the social history, size, resource endowment, development strategy of the various countries and sub regions. We will identify at least 3 "clusters" of countries (with exceptions inside each of them): Central America and the Caribbean; Andean countries; and the southern cone countries (to which should be added Mexico: See the "Governance" section). This brings to light the fact that, beyond explicit governance (Councils) there is an implicit one (several actors in a segmented system). And we'll have to question the resulting force (Science policies, Action Plans and in the last resort the legitimacy of science).

Indicators confirm that there is a high level of enrolment in tertiary education (over 20 % of each age group in Central America and the Caribbean, 30 to 40 % elsewhere and even 60 % in Argentina)[112]. But there is *no straight correlation* with the output of research (e.g. in terms of ISI publications).
Other indicators show that there is a large spectrum of nations' wealth (ranging from 3 000 $ to 13 000 $ GDP per capita) with its breakdown positioning the Continent above the others but again without a direct link to the investment into science (e.g. the expenditure in R&D: GERD as a % of GDP).
Descriptors show that the establishment of Universities is generally old, as well as the institutionalization of *research in some countries*.

Historical setting

Latin America illustrates the ***long march*** allowing the carving out of a space for science.

[111] From import substitution, auto centred and "developmentalist" options, to the wildest liberal policies implemented at the opposite of the world trend: Argentina: 1976-1983.
[112] While this enrolment is around 30 % in some Asian and Machreq countries (but more often around 20%), and 1 to 10 % in Africa (most often 4 %).

Monographs document the *long effort devoted in most countries to universal education*, at all levels. About research, the story is different. Concerning for example Argentina, H. Vessuri in a very documented paper[113], distinguishes three main periods:

* the *formative* period (1880-1915) during which vocations grew and founding fathers (often expatriates or immigrants) won devotees in some key institutions (outside the university, or in the 3 main Universities which developed the explicit project to go beyond professional training and integrate research and experimental thinking in the degree courses).

* the *institutionalisation* (1916-1945) took place when sufficient talents were available and went in search of a "national soul". A number of autonomous research institutes were established inside (and sometimes outside) the Universities. And the State (under the pressure of industrialisation and urbanisation, and pushed by the ideals of progress and modernisation) established for its own needs laboratories which for a while were a model in their kind. Soon the intellectual field became more autonomous. Norms of scientific (and technological) rigor were internalized. Learned societies prospered and a scientific community took shape (with its own powerful organizations).

* the next period (1945-1975) is one of disputes between the government and the academy (supported by the scientific community), but also the time for a new *professionalisation* in the framework of ambitious programmes (e.g. nuclear), large teams, and a combination of basic and applied research.

* the officializing of *a government for science* is late: CONICET is created in 1957, and the first document of science policy can be dated of 1950.

Though with variations, it is possible to identify the same steps of this slow maturation in most of the countries of Latin America. The first Universities appear almost everywhere at the latest at the beginning of the 20th century. But the formative and the institutionalisation stages of research may be late (Venezuela).

2. Governance and Policies.

We'll stress three features in this section :

- The first government framework appeared rather late and took on the *similar and original shape of "National Councils of S&T"*, throughout the Continent.
- Nevertheless, beyond this "explicit governance" configuration there may also be more implicit ones, and *deep differences in science policy*. We'll distinguish three clusters of countries, with different 'trajectories" regarding their interest and strategy vis-à-vis S&T.

[113] Bitter harvest : the Growth of a Scientific Community in Aregentina, *Scientific Communities in the Developing World*, Sage: Delhi, 307-353. See also in the same book: R. Rengifo, A. Pirela & R. Arvanitis, Science and Production in Venezuela: Two Emergencies, p. 354-380.

- Since a decade this *scientific order is changing* quickly. There is a shift in policies and governing bodies, as the function of research is reconsidered. This is mainly true in some countries, and the gap between clusters is deepening.

Explicit governance: The National Councils for S&T.

In spite of its long and brilliant history of modern science, Latin America did not inscribe research *as an affair of the state* up to the beginning of the 1960s. Indeed in the first old "formative period" the state had been "the main patron" of research and educational programmes. But their initiative and organization were left to key figures, undertaken by autonomous Institutes or Faculties, and regulated by the burgeoning scientific community. *State is not here the demiurge* of Science, as it appears to be in other parts of the developing world (Africa, Maghreb, parts of Asia).

It is under the double pressure of a mature scientific community, and of international bodies (UNESCO was very instrumental) that most governments came together around the idea of research being a lever for development, which needed planning, and a permanent concern of the State. This idea was embodied in the institutional framework of National Councils, in charge of designing a national policy, coordinating foreign cooperation and administering budgets mainly provided by the public sector. These Councils were autonomous and under the control of specialists – mainly the scientific community. Their benefit was to ensure a minimum attention of the State whatever the government of the time and to guarantee a long term competent management of scientific endeavours.

This arrangement has been *sustainable* and successful in many instances. It persists in most countries, though in a number of them (Chile, Costa Rica, Argentina…) it has been recently reduced to the function of administering funds rather than policy making. This in turn is the result of a permanent undercover split in the scientific community, between "academic" supporters of fundamental research, and advocates of an applied "useful" one. National Councils (often under the control of the former) never really brought to a close *the dispute between "excellence" and "relevance"*, as the main function of research.

Science policies: three clusters of countries.

Beyond the explicit inscription of Science among governments' concerns, it must be acknowledged that "*real policies*" (translated into budgets and action plans) are very diverse.

The private sector is supposed to be an actor, though its contributions are generally weak. Contributions by the state come from different Ministries, which have their own agendas and often operate their own Institutes. They may also come from state owned powerful companies which are in the same position, and do not really care about the National

Councils 'agendas (Venezuela). One result is that *the system is fragmented*, with weak coordination. Another one is it may happen that main actors are *not convinced by the legitimacy of the research* offered by National Councils and do not support its funding.

This is why science policies may vary from intense support to pure laissez faire. We'll distinguish ***three "clusters"*** of countries, according to *the "**trajectory**" of their interest* in Science.

a) ***Central America and the Caribbean*** are small populated countries, with ethnic diversity and deep social inequalities. Their records in qualification of the labour force are poorer than elsewhere in Latin America. The GDP per capita is low, but not in all countries[114]. Up to a recent past, these countries did not voice any concern for S&T. Even when rich, they are not interested in industrialisation (but rather in the development of services and trade). So, they do not care much for research. They have no "National Councils" and it's only in the recent past that some of them have shown public interest by establishing a Ministry (T&T: 2002) or strategic plans (Panama: 2006) and dedicated organizations and bodies (Jamaica: under the authority of the ministries of trade and of industry). Nevertheless their option remains one of **laissez faire.** They do not consider their future through activities using intensively S&T knowledge. As several monographs note, there is no incentive policies to encourage private investment in research or innovation, and there is no unified and steady science policy. Expenditure on R&D is poor (0,1% to 0,2 % of GDP). The universities have no mandate for research (except at their own initiative: West Indies University is an example[115]). The output fluctuates depending on grassroots initiatives and foreign cooperation. Globally, it can be said that there is little political interest in R&D, and the attention to S&T issues is thin and new. ***Exceptions*** in that zone are *Cuba and Costa Rica*. **Cuba** has been for long supporting science and research considered as « productive forces ». Expenditure in R&D is the highest in Latin America (0,65 % of GDP). There are numerous high-quality Institutes and university laboratories, with up to date collaborations abroad. The main thrusts are in medicine, biotechnologies, and all kinds of basic research. Observers consider that its scientific potential is now an important asset for the economic future of the country – whatever its regime). The other exception is **Costa Rica** which puts important stress on diversifying its economy, facing globalisation and upgrading its industrial potential. It managed to set up some well known "Triple Helix" endeavours, attracting foreign enterprises and organising technology

[114] Generally around 3000 US$ per cap ; but 6400 in Panama (benefiting from the opportunities of the Canal) and 10500 in Trinidad & Tobago (which is rich of oil).
[115] This is at the clever initiative of individuals and small teams, in the field of Agriculture, Medical and Social sciences and through the ways of an original action research in topics of health care, dealing with poverty, and some industrial small projects. Funding comes from different ministries, and from foreign Agencies.

transfers (e.g. a long term agreement with Merck in a joint venture to explore and value the local pharmacopoeia). Expenditure on S&T is important (0,4 % of GDP), there is a constant effort since 20 years (a National Council since 1972, and above all a Ministry and policy documents since 1986). Since the 1990s the motto has been "innovation". In many respects, Costa Rica looks like Argentina or Chile to day (see below).

b) another cluster is that of ***Andean countries***, which began much earlier with the development of Universities and the establishment of a few renowned research centres (like IBBA in Bolivia or INGEMET in Peru: geology and mining). The National Councils were established as in other countries of the sub continent (1968 in Colombia with its planning and funding wing COLCIENCIAS, 1969 in Peru and Venezuela). But the investment in R&D remains at a low level for many decades, the potential is declining (many brilliant scholars have left) or resigned due to the mediocrity in poor standards establishments (cf. monograph Peru). However there are *ups and downs*. There was a revival in Peru in 1975-1980 (GERD = 0,35 % of GDP, instead of 0,1% before and after); another one in Colombia (with the "1990 Law 29" and an important boost to COLCIENCIAS). In *Venezuela*, a significant batch of measures has been promulgated through successive National Plans, since 1976 and the creation of a dedicated Ministry. They ensure contributions of the enterprises (through taxing) and insist on the need to stimulate the technological development: one can say there is here a research system, with an influence of economists and planners. Venezuela could well be an exception in the Andean cluster and aim seriously at an "innovation path". Nevertheless the *"trajectory" remains unsteady, there is dispute* over the function of research, and in spite of references to a policy of innovation the action plans place a great deal of emphasis on traditional activities (either scientific or technological, oriented toward industries with scant added value and limited use of know-how).

c) On the contrary countries of the ***southern Cone*** (Chile, Uruguay, Argentina) recently turned to run for the status of ***emerging countries*** - as Brasil ***and Mexico*** are already. They are boosting their support to R&D.

Science here has a long tradition, founding fathers, dramatic gestes (as the story of aeronautics, or the nuclear endeavours of Argentina). Past Nobel prizes and vigorous key figures went down in legend. Vocations are plentiful and a scientific community is established. National Councils were created decades ago. Nevertheless political turmoil often caused the collapse of science establishments, exile and persecution of hosts of researchers and abrupt withdrawal of any support to Science.

What is new is that since eight to ten years, these countries are more stable. They are now betting on a change in their economy and on sustained *innovation* of their enterprises. They are renewing their science policy in order to link the achievements of science to this new goal. This means too that they give *a new legitimacy* to research (even in basic sciences) and they take it seriously enough to rebuild their science system. Their new doctrine (innovation) probably entails its share of reforms of the institutions, and even of the professional model of a number of researchers.

For example, Mexico (which we include in this cluster) has successfully developed since 20 years an original « Sistemo Nacional d'Investigadores » restricted to the « real » researchers (those who accept to submit to a periodical strict assessment in exchange for personal notable bonuses and facilities to conduct their work). In parallel a number of funding mechanisms have been established to encourage firms to invest in R&D and researchers to collaborate with them in joint projects[116]. *The expenditure on R&D* is clearly more important than elsewhere on the continent, and significantly growing (0,4 % of GDP in Argentina and Mexico, 0,65 % in Chile). Results are growing too in terms of international publications as well as patents[117] and collaborations between firms and academics.

The Function of Research: a debate.

Governance and science policies, in their *substantive* content, depend on the recognition of a research *function* by the government and the society all around. In all Latin America countries there are sufficient organs for research: Universities and State institutes (some of them with an ancient research culture), dedicated Centres (public or private, and renowned), extensive human resources, governing bodies and their information system. Does this whole apparatus function as a system? Are these organs specialized, interdependent, and capable of auto correction if one of them fails? Are they working together toward a common goal, as those of our digestive system which contribute to a vital function in our body? A number of countries seem not to be convinced by such a function of research. The Andean countries are hesitating.

Should science target "Excellence" or "Relevance" in developing countries? This unremitting debate, within the very scientific community[118], obscures the perception of research and involves many issues of organization (which preferred performers?), funding (which fair share for fundamental research?), evaluation (which criteria?), partnerships (world scientific

[116] See details in monographs : Argentina, Chile, Mexico.
[117] Though this is not the most spectacular result. See the Indicators section, and the trend in monographs.
[118] Cf R. Rengifo, A. Pirela & R. Arvanitis, 1997, "Science and Production in Venezuela: Two Emergencies" in *Scientific Communities in the Developing World*, Sage: Delhi, p. 354-380

community or local stakeholders?), etc. Which knowledge is worth being pursued in one of these countries, and is knowledge creation a public affair?

By adopting *innovation* as the social objective including research, a group of countries now sets forth a new legitimacy of science, removing it from the trap of the "great divide" between excellence and relevance. There is room in the new function for a continuum of researches, spreading from fundamental to applied and development projects. But there is also the need to reorganize institutions, professional practices, topics to be tackled, and the social inscription of science.

3. Institutional Framework.

It has been said in other reports (Africa, Asia) that three main conditions should be completed for a modern science system to work. Namely:

- There is a core of relatively stable and well-resourced scientific institutes
- There is consistent government and industry investment in these institutes
- Scientific institutions flourish under conditions of economic and political stability and within a science governance system that allows for their autonomous and relatively independent operation

One can say that the 3 conditions are now fulfilled in the cluster of "emerging" countries. Sufficient funding and steady local investment are lacking in the other clusters. Universities and Institutes have to manage on their own if they want to develop a research scheme. Their professional culture did not always prepare them for it.

Strong potential

Latin American countries have (most of them) a great number of Universities. The gross enrolment ratio in tertiary education is higher than in other parts of the developing world. It is at least around 20 % (in Mexico and the Caribbean : this would be a good level in Asia or in Arab countries); more often around 30 % (in Cuba, Peru and Colombia: the best level in Asian and Arab countries); and generally around 40 % (culminating with 60 % in Argentina: a level of developed country).

The number of academics is therefore important (they are 200 000 in Mexico and 130 000 in Argentina; nearly 100 000 in Colombia and Venezuela; around 50 000 in Cuba, Peru, Chile; and around 10 000 in less populated countries[119].

Numbers of full time researchers are employed in government Institutes (notably in agriculture and health) or in private Centres and Foundations. In some cases, important

[119] Only 2 000 to 5 000 in some Caribbean countries : Jamaica, Trinidad and Tobago, and in Costa Rica.

firms (often government owned: Oil in Venezuela, Mines in Chile…; but now also multinational firms in automotive, ICTs or pharmaceuticals industries) have their own research Centres.

It is not easy to determine the number among them who are *actually involved* in research; and the share of their time devoted to this activity. Numbers are clearly much under the previous ones. Some countries have tried to evaluate them. *Mexico counts 12 000* persons accredited by its “researchers’ national system” (thanks to their good publications record: see below). Other people (probably as many) practice research of another sort (more applied). The total number (headcount) reported to UNESCO is around 30 000. Venezuela too has an assessment system. Its researchers’ programme includes a little less than 3 000 persons; and the total number of researchers reported to UNESCO is 6 000. *Chile is supposed to have 7 000 FTE* researchers. Other countries are rather around 1 000 (a few hundreds in the Caribbean countries).
Such figures are about one tenth of the teaching staff at Universities. They may seem excessively harsh, compared with the numbers of potential researchers. It may be a problem of definition (what can be called research?). But it points also at some problems of efficiency that appear in the very monographs.

Some weaknesses of present institutions.
Several monographs state a number of structural features that become drawbacks as soon as “innovation” is given as the entire reason for research.

One is that *local doctoral studies are a rather new thing* in many countries, without know-how to launch them[120]. The monograph dealing with Peru puts forward the great number of scattered and mediocre Ph D courses, with a poor yield: 9 PhD’s per year for all the universities in all disciplines. Similar assessments are done regarding other Andean and Caribbean countries (Cuba is the notable exception). There seems to be a need for institutional rigor (assessing, selecting, networking to get external support) in order to round this cape.

Another feature is that in some countries (and even at the university) values of “excellence” are “discredited”. This is reported for Peru, but also for Chile; and it may occur in other places. There seems to be *a need to raise ambitions*, take part in international programmes and gain insights into the important stakes of global scientific and technological issues.

[120] Simultaneously there is a need to create them (with teachers who are not always up to date), to support them with choice collaborations abroad, and to maintain a fair share of grants for trainees in foreign countries. Several countries have already bypassed these reefs: Mexico established its national board of masters in 1976 (with accrediting commissions); Chile, Argentina and Venezuela did the same long ago.

Almost everywhere, active researchers are overwhelmingly committed to fundamental science; and this is the sort of research which is valued by their institutions and management. This is an important asset. But the ratio may be excessive and there is a need to develop (especially among young scholars) a new culture, *a taste for applied research*, acquaintances in the productive sectors, and recognition for that. This means new incentives, at the level of individuals *and* of establishments (which could be encouraged by new formulas of funding).

Government institutes and Centres are also challenged. They may have been at some time the main source for new technologies, products and processes offered to local firms and national "import substitution" projects. It is no longer so (as economies are opening). *Their mission has to be rethought*.

A final challenge is taken seriously by the largest countries: that of *decentralizing* their research machinery. The objective is to bring closer (and if possible together) researchers and the stakeholders. But most of the Institutes are concentrated in the capital city (or in the small part of the "useful country"). And the best renowned research Universities are located in the same area. A number of countries (Argentina, Mexico, Chile, Columbia…) are now considering means and incentives to move the capacities, and build dispersed "clusters" conducive to innovation.

Structuring research

In order to face a necessary "*re institutionalization*" several countries (particularly emerging ones) took original initiatives which are worth being mentioned.

The first one is to establish a more rigorous running of the "research and innovation system". In various countries *a Ministry* for S&T has replaced the National Council for the tasks of policy making, planning and setting up indicators and control mechanisms. There are now Ministries in Costa Rica (since 20 years), Cuba, Argentina and Venezuela. In Argentina, there is a Cabinet for S&T and its permanent "Secretariat". In Chile, there is a National Commission for Innovation which coordinates the system. In Colombia the Fund for research (COLCIENCIAS) has been attached to the ministry of Planning. The National Councils retain an advisory function, and become basically national Agencies for the funding of research. An interesting device in Chile has split up this Agency into two main Funds: the ancient CONICYT which funds fundamental research, upper training and the creation of regional research Centres; and the CORFO which includes a representation of the industrial interests and funds innovation, R&D in the regions, applied research and transfers of technology. Both organisations are under the supervision of the National Commission for Innovation. Moreover, *Observatories* of S&T have been established in

Colombia, Venezuela (and the regional Observatory RICYT checks the data collected by specialized government services in several countries).

Another important step has been the creation of several *Funds specialized in selected goals*. Chile again is a good example. Besides CONICYT and CORFO, the National Commission operates through FONDAP (advanced research in priority new areas), FONDEF (for research in Universities where it lags), FONDECYT (to boost research in underdeveloped regions), FONIS (health research), CHILE INNOVA (technological innovation) and other tools contributing to the coordination of private and public initiatives in research, technology transfers, the dissemination of scientific information, and the development of human resources (doctoral studies: the output is rapidly growing; post doctoral internships: agreements are actively searched for in foreign countries).

A main idea is to *concentrate resources on "real" players*. Mexico was the first to establish a "*National Researchers System*" (in 1986, now imitated in several countries: Venezuela, Uruguay, etc). In the beginnings, the reason was that the profession was severely hit by inflation and loss of purchasing power. Vocations were drying up, and there was an exodus among researchers. The idea was to rebuild the scientific community from its very basis, by offering a notable bonus to the researchers who would submit themselves to a recurring assessment taking into account proven *results*. There are several ranks in the system (which became sophisticated). In spite of initial suspicion, this mechanism gradually gained popularity. It encompasses now a large part of the active academics[121] and the publications in international journals made progress at a brisk pace.

Another way to concentrate resources is the creation of "*Centres of excellence*", which some countries are now considering (Chile is an example). In all cases *assessments* are prerequisites, and a new culture of evaluation is emerging. Through this and the new competitive ways of funding institutions are changing and the professional models too.

Nevertheless, there is yet a long march before the re institutionalization needed to establish a connection between the worlds of research and production, or those of fundamental and applied research has been accomplished. And there is a growing gap between the "emerging" countries which express the will to develop S&T and take steps to build a coherent research system, and those of other clusters which are hesitating, or which are not interested and implement a laissez faire policy.

[121] It is not restricted to Universities: other researchers compete. But the weight of international publications in the evaluation favours the academics.

4. Human Resources

We already gave an indication of the large research potential of Latin American countries. As H. Vessuri puts it for Argentina "the availability of highly qualified staff was not a problem for scientific and technological development, except for individual specialities. More problematic has been the countries' inability to retain [their] scientists".

This general statement should be complemented with some remarks:

* The numbers are impressive. There is a real S&T milieu. But the *research potential is concentrated* in a few flagship establishments[122]. Out of their boundaries the staff may be of poorer quality, with restricted ambitions and limited activity[123]. By contrast some researchers are brilliant scientists, cosmopolitan, much sought-after and well connected through the world, credited with important contributions to national and international science.

* Therefore *key figures* always played (and continue to play) a very significant role in the development of S&T, arousing vocations, launching establishments and defending the autonomy of science vis-à-vis the state and the whole society. *Centres* have become the locus of the scientific activity, circles of specialists where the talents were nurtured, rather than large programmes and government Agencies.

The Profession: Manhandled and unwavering:

Unfortunately, *since decades Latin America has rather ill treated* its scientists. Indeed "low salaries, continued political and economic instability, and frequent persecution and repression" hit intellectuals, academics and scientists prolifically. They "contributed to the emigration of a good portion of scientists and engineers and discouraged the vocation among many young in the recent decades"[124].

Brain drain

Such a ***mishandling of the professionals*** led nevertheless to a serious weakening of the quality in tertiary education, resignation to mediocre fate, marginalization of talented people, renouncement of bold endeavours and of great hopes in new industries. Above all it led to a tremendous brain drain[125], which took some scientific communities (notably the smallest) on the verge of ruin. Since the crisis of 1930 this phenomenon hit different countries at different times for shorter or longer periods. When Mexico established in 1986 its "Researchers' system" it was just time to rescue what was left of a previously bright scientific community.

[122] 2 or 3 Universities in each country : generally the « Central » and often the « Pontifical » (plus 3 or 4 in a large country like Argentina, and a total of 1 in Caribbean countries). To this should be added a small number of renowned Institutes (public or private, and often founded by historical key figures) plus parts of government and industry Centres. The bibliometric data are clear on this point.

[123] Even in Argentina, in 2005, 60 % of academics and researchers had qualifications under the Master degree, and 25 % only had a Ph D.

[124] H. Vessuri, « Bitter harvests…", op.cit.

[125] Beginning with the most connected and brilliant scholars

In Argentina, the 1960s and 1970s political problems motivated severe emigration. In the 1990s economic reasons took over (low wages, unemployment and collapse of national sophisticated industries). In Colombia migration of the highly qualified people is impressive. Chile (under the military dictatorship), Venezuela or Bolivia now and then, the *Caribbean countries* intensely and permanently are other examples.

In 2003, Jean Johnson, from NSF, published *very detailed figures* of the foreign residents holding a degree in Sciences and Engineering and living in the USA.[126]. By the turn of this century, Latin America provided about 200 000 degree holders to the United States: nearly half coming from South America and half from Central America and the Caribbean.
Among them, 30 % worked in the R&D sector. This makes high numbers, if compared to those working in their home country in the same sector[127].

For these Latin American degree holders working in R&D there are three main patterns :
* Those working in USA *outnumber* by far those working in their home (*Caribbean*) country.
* Those working in USA are *equivalent* to those working in their home (*Andean*) country.
* Those working in USA are *less* than those working in their home (*Cone*) country. But the expatriation is significant among Argentinean (and to a lesser extent Chilean) degree holders: 1/5 to ¼ of the scientific community has left for the USA.
There are minimal exceptions (Uruguay, Costa Rica).

These figures concern only the emigration to USA. The departures to Europe are not trivial. It can be said that ***brain drain is a massive and structural problem*** for Latin America. The (tertiary) education sector produces qualified scientific human resources. But the development sector does not seem to be in a position to integrate them. And there is not room enough for them in the academic and the research structures (or they are not attractive enough). In some cases the scientific community is threatened by extinction (or by involution).

To halt this trend there is a clear need of new incentives for researchers, and for a re professionalisation of young generations improving their links with society and production.

Toward the revaluation and re professionalisation of research work?
Various remedies have recently been applied, as governments occasionally expressed their concern: better salaries, new positions in the academic sector (with the role of a sanctuary for research, on hold of its demand by the productive sector) and attempts at benefiting from

[126] Jean Jonson (NSF) "Quantification of the scientific diasporas" in R. Barré, JB Meyre etal. Éd *Diasporas scientifiques / Scientific Diasporas*, 2003, Paris:IRD, 197p + CD-ROM
[127] Almost all had become citizens or permanent inhabitants of USA. 9% had a Ph D, and 20 % a Master. This reflects the late organization of doctoral studies on the continent. Nevertheless their employment in R&D was important.

the brain drain through organized links with the diasporas ("brain gain": see the well documented case of "Red Caldas" in Colombia[128]).

But the "innovation" option alone is trying to tackle the question through an integrated policy. The presupposition is that globalization gives an opportunity for the modernization of the productive sector (or requires it). The suitable human S&T capital should not be lost and it should be enhanced. This is why a revaluation of the S&T profession should be designed, together with a re professionalisation linked to the economic policy.
The very dereliction of the scientific community gave an opportunity to concentrate efforts on a group of 'real" researchers of suitable size. While receiving attractive bonuses they have to prove continuously their results. New patterns of funding direct the activity toward strategic research, and consolidate a competitive behaviour. This is the action plan of "emerging countries" (e.g. through "National Systems of Researchers" – see above-, to be complemented by adequate targeted Funds).

This policy is too new to be assessed. But a look at the output gives some first hints.

5. Output

Publications in international journals are one of the outputs of research. They are generally a good sign of the general health of the activity.

In the case of Latin America, measures over a long period (the 20 last years) show that:

* in spite of ups and downs in the governments' support to R&D, scientific communities managed to *maintain* at least a minimal production.

* nevertheless, the size of the country, which is linked more or less to the size of the scientific community, makes a difference. In "small" countries, with very small communities (less than 600 researchers) the production is erratic. It relies on a few people and it is sensitive to fortuitous events (withdrawal of one person, efficient international collaborations, launching or completion of a particular programme…). There are a few areas of competence (sometimes very specific topics) and in each of them there is a problem of critical mass.

* in "intermediary countries" (sizeable countries and communities: around 1000 researchers; e.g; Andean countries) the production is very sensitive to the policies (or to the action plans) of the government. Colombia is an example (leap forward in 1996-2002 accompanying a strong action of COLCIENCIAS), Peru another one (short bright spot in

[128] R. Barré, JB Meyer et al. *Scientific diasporas*, 2003, Paris :IRD, op. cit.

1999-2003). When the support withdraws there is a quick return to the normal (stagnant) production assured by the small circle of devotees.

* There has been *a powerful impact of the "National Systems of Researchers"* (e.g. in Mexico and Venezuela). More generally the countries which implement an *"innovation option" enjoy the most sustainable growth of their production*, taking them now at appreciable scores (Argentina, Chile, Mexico). It should be noted that their option is not so old, and beforehand they experienced the throes of mishandling of the scientific community (See the regional Report). They did not yet make the same take off as Brasil (an emerging country in the true sense, which implemented its science policy earlier).

Other outputs.

Other outputs are more difficult to measure. *Patents* is one item. The monographs show that there is a noteworthy growth in the cluster of « innovative countries » (e.g. see Mexico). In other cases the figures are very low. And patents are probably not the best way to communicate with the social (and even the productive) sector. But there are others, about which we lack data: continuing education, services to industries or communities, support to technological learning, adaptive research and *action research*… All these sorts of activity, especially when carried out under contracts, should be considered as interesting outputs. There are some good examples of such practices run even in countries which have no specific science policy, like the action research handled by the West Indies University in the Caribbean. This may be more efficient than a lot of so-called "applied research" that won't ever be applied because it did not involve users in its design.

It must be acknowledged that there is a ***need for data*** and on this sort of results (e.g. number of contracts, amount and purpose).

CONCLUSION.

To conclude, we may stress the following points:

* Latin American countries have *an ancient record* of education (including tertiary education) and a long history of institutionalisation of science. They have professional scientists and they built scientific communities earlier than most other countries in the developing world.

* Nevertheless the *support for science is unsteady* and since more than half a century the story of relations between the State, society and the scientific community has been a stormy one, full of sound and fury and leading to harsh mishandling of technicians and scientists (low wages, unemployment, often persecution). This led to a *severe brain drain*, which has become structural.

* By now there are *three main clusters of countries*:
- one with “laissez faire” policies, not really interested in science or technological development. They may be rich and considering to diversify in services and trade, or poor and focusing on immediate urgency; but they restrict the function of universities to professional training and they nurture very small scientific communities. Many Caribbean countries are in this cluster. Interesting exceptions are Cuba and Costa Rica.

- a second cluster (mainly Andean countries) is hesitating about the function of research. They may have action plans and suddenly withdraw them. A number of devotees and committed people champion science, and struggle to relate its endeavours to socio political expectations. When they fail (temporarily) they have to rely on external support. The output is sensitive to local policies and safeguarded by a few universities and international cooperation. Its level remains mediocre and it has ups and downs (by now: rather downs).

- the third cluster consists of countries (mainly in the Southern Cone, but also Mexico, and probably Venezuela and Costa Rica) which since a few years have rallied to an “innovation (economic) policy”. This gives research a *new and clear legitimacy*, but also requires some *re institutionalisation of S&T and a reprofessionalisation* of the researchers. Vigorous action plans are implemented and they seem to bear fruit. Consequently, these countries have entered into a path of “emerging’ countries, but *the S&T gap is deepening* between them and the others.

* Finally, we must acknowledge there is much more significant information available on Latin America than on other continents. This is of course due to the quality of the monographs, prepared for this Report. But also, and structurally, to the fact that there is a scientific community specialized in those topics; and Observatories (notably a regional one) dedicated to them. *We like to recommend this as a model*. It does not prevent from developing *further efforts in order to collect relevant data* – always missing- about qualitative determiners of the spread of research, and about efficient *outputs (other than only publications* in professional journals).

SECTION 4: THE COUNTRY REVIEW TEMPLATE

This section comprises three parts. In Part One we present the basic "skeleton" of the Template we propose. This is followed by an illustration of how one would use the template in a country study through examples from a selection of our 52 countries. It is thus presented as a kind of "Annotated Template". In the final section we make some proposals on the Methodology to be followed when applying this template in future country studies.

4.1 THE BASIC TEMPLATE

The template that we propose is based on what we have learned from our analysis of the 52 country reviews as well as a comparison with other existing approaches. Much of the detail that is proposed in the template has its origins in specific country studies. However, few if any of the individual country studies would comply with the proposed template. In fact, we would argue that the template be seen as an ideal-typical framework that suggest (optimal) good practice in constructing a country study or profile. It should be seen as a heuristic framework that suggests categories and themes as well as different forms of information and data. In many cases information might not be available on every one of these categories. For some countries, some of the proposed categories and variables might be inappropriate. The application of this template in practice therefore still requires insight and judgment on the part of the researcher.

The template proposes NINE categories (or topics) to be covered in a typical country study. It also proposes THREE different kinds of information and data to be collected and presented in such a study. These are:

- Statistical indicators (Social, Demographic, Health, Educational, Science, Technology and Bibliometric)
- Descriptors: quantitative or visual descriptions that present the facts of a certain category of entities or events. We distinguish between Listing descriptors and Diagrammatic descriptors.
- Narratives: More elaborate and deep historical and contemporary descriptions of aspects of the research system in a country.

Category	Description	Nature of data
1. Contextualization of the science system within broader political, economic, educational and social systems	*1.1 This section contains a brief narrative description of the political and socio-economic "status" or "climate" of the country highlighting significant strengths, weaknesses and major events and developments.*	*Historical narrative*
	1.2 In addition a set of uniform tables listing demographic, social, economic and technological indicators should be included.	*Statistical indicators*
2. Some considerations about the History of science in the (country, region) under review and especially the development trajectory followed.	2.1 Date (decade) of establishment of first research institute (s) Date of establishment of first public university Date (and names) of first scientific journals Date of establishment of academy of science and/or first professional societies Date of establishment of dedicated ministry for science, research and/or higher education Date of first science policy and HE policy documents	Descriptors (listing)
	2.2 Description of specific models of scientific organization and governance as influenced by colonial and other powers historically Major periods in the institutionalization of science in country Major events shaping the development of HE and science in country	Narrative
3. *The governance of science in the country and available policies (especially S&T, R&D and HE)*	List of science policy, research strategy and HE documents as well as formal reviews and commissions into HE and research in the country	Descriptors (listing in chronological order)
	Research and science priorities as identified in science policy documents	Narrative
	Diagrammatic representation of science governance	Descriptor (diagrammatic)
4. *Knowledge and R&D performers (Establishments/ Institutions/ Universities/NGO's)*	Names of public universities Names of private universities Key university/college research centres Key government funded research institutes/ centres Key internationally funded research institutes/ centres Key private sector research facilities	Descriptor (listing)
	Description of strengths and weaknesses of the university system Niche areas of research in the system and at universities Nature of knowledge production undertaken in various sectors of the system	Narrative
5. *Informal S&T structures (Academies, Associations, Trade unions, Journals, etc = Scientific Community)*	National scientific journals Scientific societies and associations Academies of science	Descriptor (Listing)
	Status of main journals (still being published or not) (Historical) description of information structures	Narrative

Category	Description	Nature of data
6. S&T Human Resources (Description/statistics + **T**he Profession of researcher: status, salaries, etc)	Number of researchers/ scientists in country Number of academics in HE institutions Number of PhD students Number of researchers per million of labour force Nr of academics by scientific field Nr of academics (gender breakdown) Number of academics in HE institutions per million of labour force Nr of Masters and Doctoral students (enrolments) * gender Nr of M and D students by field of study (6)	Indicators
	Profession and status of academics and knowledge workers Remuneration compared to other public professions Scientific mobility and brain drain challenges	Narrative
7. Research Funding (Public or private; National and international; Trends)	R&D intensity (GERD/GDP) Expenditure on R&D per researcher Expenditure by sector Source of funding (incl. overseas agencies) – actual values and proportions Expenditure by scientific field (6)	Indicators
	Role of government and other domestic agencies in funding research Role of international donor and funding agencies in funding and steering research in the country	Narrative
8. Research Output (post-graduates/ publications/ papers/ patents)	Total output in ISI-journals (by scientific field) Total output in local journals (by field) Nr of Masters and Doctoral graduates Nr of PG theses/dissertations Nr of patents Niche areas of research and impact of publications	Indicators
	Description of specific policies (funding, incentive) and initiatives to encourage a participation in innovation, technological learning, and research publications locally and internationally	Narrative
9. Scientific co-operation and agreements	Nr of bilateral scientific agreements Nr of multilateral and regional agreements Nr of international agencies operating in country Degree of scientific collaboration as measured through share of foreign co-authors of papers Nr of bilateral scientific agreements Nr of multilateral and regional agreements	Descriptors (Listing)
	Main international and regional scientific partners	Narratives
	Main institutional collaborators	
	Domains and topics of scientific research	

4.2 THE ANNOTATED TEMPLATE

The aim with this section is to show how one would go about in "populating" the template when conducting a country study[129]. We have attempted to illustrate the application of the template through selected examples from all four regions covered in this project. It is important to emphasize that the application of the template is not a mechanistic process. Our selection of examples already illustrates how different authors have applied the same category in the template differently. The availability of specific information or data within a category obviously also determines how complete or detailed the application of the template will be. And finally, it should also be obvious to the reader that complete coverage of all categories and sub-categories in this template is not only a huge task (given current data availability more likely an impossible task), but also a very time consuming task. It is for this reason that we have emphasized in Section 5.1 that the template is best understood as a heuristic framework that should guide scholars in conducting country studies.

Section 1. Contextualization of the science system within broader political, economic, educational and social systems

This section contains a brief narrative description of the political and socio-economic "status" or "climate" of the country highlighting significant strengths, weaknesses and major events and developments.

In addition a set of uniform tables listing demographic, social, economic and technological indicators should be included.

EXAMPLE 1: BURKINA FASO

General introduction to the country and the S&T system.

Burkina Faso is the only African country to have maintained a small but permanent growth during the past decade. From 1986 to 1991, it was of 3.5% (mean per year) and inflation stayed behind 3%. However, economic results entirely depend on external factors : mostly climatic ones but also foreign investments. Conscious of this dependence, Burkina Faso has tried with its limited possibilities to use scientific research as a means to strengthen and ensure a continuous growth. This policy depends on competent people constituting the political elite and reckoned as experts in their domain.

Burkina Faso remains an agricultural country. The agricultural sector has been led by a few major companies: the Office National des Céréales (OFNACER), the Société des Fibres Textiles (SOFITEX, cotton) and SOSUCO (sugar). The Société de Recherche et d'Exploitation Minière du Burkina Faso (SOREMIB) performs mining activities (gold, manganese) with the Canadian company Interstar

[129] All the examples in this section are taken from the country studies contained in the regional compilations. The fact that we have selected examples from different countries unfortunately means that there is an inevitable loss of context.

Mining Group (COMITAM). Four companies dominate the services sector: SONABEL distributing electricity, ONEA distributing water, ONP and ONATEL specialize in telecommunications technology.

Burkina Faso is one of the ten poorest countries in the world. Paradoxically, it has become a reference for other African countries in the way it organizes and manages scientific research. As in many countries, research is highly depending on political will but here it did not lead to mismanagement.

Indicators

Demographic indicators

Indicators 1975-2004	Total population (2003) (1)	Population under age 15 (2003) (1)	Urban population (1975) (1)	Urban population (2003) (1)	Migration stock (2000) (2)	Annual population growth rate (1975-2003) (1)
Measure	Million Inhabitants	(% of total)	(% of total)	(% of total)	(% of population)	%
	7.9	**44.8**	**21.9**	**44.6**	**1.6**	**3.2**
(1) : UNDP Human development indicators						
(2) : world development indicators						

Social indicators

Indicators 2003	Life expectancy at birth (2003) (1)	Infant mortality rate (2003) (1)	Adult literacy rate (2003) (1)	Net secondary enrolment ratio (2002/2003) (1) 1 2 3	Combined gross enrolment ratio for primary, secondary and tertiary schools (2002/2003) (1)	Public expenditure on education (1990) (1)	Public health expenditure (2002) (1)	Tertiary Gross enrollment ratio (2002-2003) (2)
Measure	Years	(per 1,000 live births)	(% ages 15 and above)	(%)	(%)	(% of GDP)	(% of GDP)	Number
	47.5	**107**	**12.8** (4)	**9**	**24** (4)	**2.4**	**2**	**1**
(1) : UNDP Human development indicators								
(2) : world development indicators								
1 - The net enrolment ratio is the ratio of enrolled children of the official age for the education level indicated to the total population of that age. Net enrolment ratios exceeding 100% reflect discrepancies between these two data sets.								
2 - Enrolment ratios are based on the new International Standard Classification of Education, adopted in 1997 (UNESCO. 1997. International Standard Classification of Education 1997. [http://portal.unesco.org/uis/TEMPLATE/pdf/isced/ISCED_A.pdf]. Accessed March 2005.), and so may not be strictly comparable with those for earlier years.								
3 - Data on net enrolment ratios refer to the 2002/03 school year, and data on children reaching grade 5 to the 2001/02 school year, unless otherwise specified. Data for some countries may refer to national or UNESCO Institute for Statistics estimates. For details, see http://www.uis.unesco.org/. Because data are from different sources, comparisons across countries should be made with caution.								
4 - Preliminary UNESCO Institute for Statistics estimate, subject to further revision.								

Economic indicators

Indicators 1975-1999	GDP per capita annual growth rate (1975-2003) (1)	GDP per capita (2003) (1)	GDP (2003) (1)	Structure of output (2003) (2)		
Measure	%	(PPP US$)	PPP US$ billions	%	%	%
	1.2	**1,174 1**	**14.2 1**	**31**	**19**	**50**
(1) : UNDP Human development indicators						
(2) : world development indicators						
Sources	World Bank.World development indicators 2005					
	The unemployment data are from the ILO database *Key Indicators of the Labour Market*, third edition.					
1 - Estimate based on regression.						

Information & Communication Technology (ICT)			
Telephone main lines per 1 000 people	3	2004	World Bank [7]
Mobile subscribers per 1 000 people	45	2004	World Bank [7]
Internet users per 1 000 people	6	2004	World Bank [7]
Personal computers per 1 000 people	5	2004	World Bank [7]
% of households with television	6%	2004	World Bank [7]
Broadband subscribers per 1 000 people	0.0	2004	World Bank [7]
International Internet bandwidth (bits per person)	3	2004	World Bank [7]
Technology Achievement Index (Rank/)	No info		

http://devdata.worldbank.org/AAG/uga_aag.pdf

2 www.cia.gov/cia/publications/factbook/geos/ug.html#People

3 http://devdata.worldbank.org/external/CPProfile.asp?PTYPE=CP&CCODE=UGA

4 www.who.int/countries/uga/en/

5 www.ubos.org

6 http://ddp-ext.worldbank.org/ext/ddpreports/ViewSharedReport?REPORT_ID=5552&REQUEST_TYPE=VIEWADVANCED

7 http://devdata.worldbank.org/ict/uga_ict.pdf

Section 2. Some considerations about the History of science in the (country, region) under review

EXAMPLE 2: BOTSWANA

Descriptors

Date (decade) of establishment of first research institute (s)	*1930 (experimental station at Mahalapye*
Date of establishment of first public university	*1982 (National University of Botswana)*
Date (and name) of first scientific journal	*Botswana Notes and Records (since 1969)*
Date of establishment of academic of science and/or first professional association	*Botswana Society (?)*
Date of establishment of dedicated ministry for science, research and/or higher education	*National Commission for S & T (NCST) in 2000 and Ministry for S&T in 2002*
Date of first science policy and HE policy documents	*Tertiary Education Policy for Botswana: Challenges and Choices and Botswana National Research, S & T Plan (BNRSTP) (both 2005)*

EXAMPLE 3: BURKINA FASO

Narratives

Description of specific models of scientific organization and governance as influenced by colonial and other powers historically
Major periods in the institutionalization of science in country
Major events shaping the development of HE and science in country

History of science

Even though the research system is not very developed, there are few structures and few human resources. It is one of the oldest in Africa. Scientific research has become a tradition in medical and agricultural sciences but is only at its beginning stages in applied science and technology.

Modern science in Burkina Faso appeared in 1923 with the creation of the experimental station for agronomic research in Saria. Although mostly focusing on the fields of agriculture, medical and social sciences, colonial research also contributed to the establishment of a tradition of scientific research in the country. The idea that research can play a major role in the development of the country arose here earlier than in most other African countries.

Colonial science

Year founded	Name	fields	status	administrative supervision
1923	Experimental station for agronomic research, Saria	agriculture	public	France
1939	Centre MURAZ, Bobo Dioulasso	medical sciences	public	France
1949	Institut Français de l'Afrique Noire, Ouagadougou	natural and social sciences	public	France
1954	Laboratoire Vétérinaire	medical sciences	public	France
before 1960	experimental stations for agronomic research, Niangoloko, Farako-Ba, Kamboïnsé	agriculture	public	France

National science

Year founded	Name	fields	status	administrative supervision	notes
1960	Laboratoire de Diagnostic et de Recherche Vétérinaire	medical sciences	public		ex Laboratoire Vétérinaire
1960	Organisation de Coordination et de Coopération pour la lutte contre les Grandes Epidémies	medical sciences		international cooperation	
1963	Centre des Techniques Forestières Tropicales	forestry	public		
1965	Centre Voltaïque de la Recherche Scientifique	natural and social sciences	public		ex IFAN
1968	Centre Africain et Malgache d'Enseignement Supérieur	evaluation of scientific activity and performers		African cooperation	
1969	Ecole Inter-états d'ingénieurs de l'Equipement Rural	planning		international cooperation	
1973	Institut Supérieur Polytechnique		public		
1973	University of Ouagadougou	natural and social sciences	Pubic		
1977	Institut de Recherche sur les Fruits et Agrumes	agriculture	Public		
1977	Semi Arid Food Grain Research Development	agriculture	international agency	international cooperation	
1978	Ministère de l'Enseignement Supérieur et de la Recherche Scientifique	coordination			
1978	Centre National de Recherche Scientifique et Technologique	coordination	Etablissement Public à Caractère Administratif		ex CVRS
1978	Institut de Recherche sur les Substances Naturelles	medical sciences	Public	DGRST	
1981	Institut Voltaïque de la Recherche Agronomique et Zootechnique	agriculture	Public		ICRISAT + SAFGRAD
1981	Institut de Recherche en Biologie et Ecologie Tropicales	natural sciences	Public	DGRST	CTFT + 1 department of the CVRS

1981	Institut de Recherche en Sciences Sociales et Humaines	social sciences	Public	DGRST	
1982	Institut Burkinabé de l'Energie	energy	Public	DGRST	
1987	Institut National d'Etudes et de Recherche Agricoles	agriculture	Public	DGRST	
1991	Laboratoire de Biologie et de Technologie Alimentaires	Food	Public	DGRST	
after 1995	Forum de la Recherche Scientifique et de l'Innovation Technologique	coordination			
after 1995	Agence Nationale de Valorisation des résultats de la Recherche	coordination			

At the time of independence in 1960, the country inherited several experimental stations end research centres. Thanks to cooperation agreements, these structures remained under French management. Quickly, the research performed in these establishments became totally isolated because of the "scientific and institutional desert". The absence of a national research system is due to a will to enter a regional network comprising western African countries. Thus, funding and energy were devoted to foreign universities such as those at Abidjan and Dakar. They were considered as national universities. That policy lasted from the independence until the 1980s and explains why in this very state, research activities long preceded a national higher education system.

Half a century separated the creation of the first research structure in 1923 and the first university, that of Ouagadougou in 1974. Even if the first generation of executives had been trained thanks to this regional cooperation, quarrels rapidly became an obstacle and Burkina Faso decided to work with France while developing its own system.

The national research system is the result of the realization of two goals: the creation of an institutional framework for research activities and the creation of a higher education system. It was revised and reformed permanently to adapt to the national context. Three phases can be defined:

- In the 1960s and 1970s, inherited structures were reformed and new ones created with the goal of establishing a national science system and using the best available resources. However, the dispersion of these structures depending on various administrative supervisions led to research being split without coordination.
- Institutionalization began with the creation in 1978 of both the Ministère de l'Enseignement Supérieur et de la Recherche Scientifique and the Centre National de Recherche Scientifique et Technologique. The latter was then divided in departments and then research institutes. It also had the mission to perform, evaluate and coordinate research programmes. Since the symposium of Farako-Bâ initiated by the new government – in power since 1983 - in 1987, a new line was defined with two main goals: to reduce the gap between fundamental and applied science in order to link research and development more systematically and to gain total independence in the leading of strategic research which is a means to get national science to be a motor of development. Actually, this period is best described as a period of the organisation and appropriation of national research resources.
- In the 1990s, the national research system was entirely reformed. That reform was the result of a pervasive "reflection" within the scientific community that gave birth to the strategic plan

of 1995. Every actor in the research system (funders, performers, users, politicians…) took part in the reflexion. The research system has subsequently evolved into two poles: the CNRST and the university, each one dealing with a specific domain: R&D for the CNRST and fundamental research for the academic world. However, the dichotomy is not so clearly marked with young teacher-researchers preferring to pursue R&D.

Section 3: The governance of science in the country and available policies (especially S&T, R&D and HE)

EXAMPLE 4: GHANA

Descriptors

List of science policy, research strategy and HE documents as well as formal reviews and commissions into HE and research in the country	National Industrial Policy (To finalise 2007) Strategic Plan for Science and Technology Development (To finalise 2007) Ghana Poverty Reduction Strategy II (2005) Draft National Health Policy (2006) White Paper on the Report of the Education Reform Review Committee (2004) The Ghana ICT for Accelerated Development (ICT4AD) Policy (2003) National Science and Technology Policy Document (2000) Ghana Atomic Energy Commission Act (2000) Ghana Poverty Reduction Strategy I (2001) Ghana Vision 2020 (1995) CSIR Act (1996) Telecommunications Policy for accelerated Development Programme 1994-2000 (1994)

EXAMPLE 5: ECUADOR

Narratives

Research and science priorities as identified in science policy documents

Research and S&T priorities: Ecuador

As a result of the institutional changes of the 1990s, the SENACYT established the bases for S&T policy which are as follows:

- Provide adequate funding for the S&T System
- Direct those aspects linked to international cooperation in the S&T sector
- Promote the creation and improvement of the necessary legal instruments in S&T

The objectives and structure of the FUNDACYT are established more clearly and indicate that the resources obtained for S&T and administrated by this foundation will come from the following sources: International Bodies with which an agreement has been established, legal or contractual allowances, voluntary contributions, donations and legacies, national public and private organizations, multinational development organizations, international bodies, governments or government agencies, or from other foreign individuals or bodies.

FUNDACYT is responsible for the programming, execution and control of medium-term and long-term policy, strategy and plans approved by the Ministry for Science and Technology.

National Science and Technology Plan 1996-2000.- The first S&T Plan had the following established objectives:

- The promotion of national scientific research projects
- The training of human resources to Masters and PhD levels
- The promotion of technological innovation within firms
- The strengthening of the National Science and Technology System through: (1) creation of the Ecuadorian Scientific and Technological Information Network (http://reicyt.org.ec/); (2) the dissemination and popularization of science; (3) the creation of a Masters Program in technological innovation; (4) the strengthening of the intellectual property system.

However, it is not clear in the document how these objectives will be achieved and it was not possible to find information indicating whether these objectives have been met.

In the Constitution of 1998 a specific paragraph is included for S&T and this reinforces the idea that the State is responsible for the promotion and stimulation of S&T at all educational levels. More specific points are also established and these include:

- The guarantee of freedom to conduct S&T activities.
- The guarantee of legal protection for research results.

- The designation of scientific research as a principal function of Universities and Polytechnics in coordination with the production sectors.
- The Statute of Scientific Researcher.
- The stimulation of scientific and technological advances in the area of health.
- The prioritizing of research in the area of agriculture
- The design of an education system based on scientific principles.
- The obligation to create infrastructure for physics, science and technology.

In 2005 a new National Science and Technology Plan was established with objectives that, from our point of view, are more specific than those of previous periods. These objectives include:

- The strengthening of science and technology capacity through the stimulation of basic and applied research, aid innovation and technology transfer to increase the country's productivity and competitiveness,
- The promotion of articulation between the productive, governmental and academic sectors

To achieve these objectives the following strategies were developed:

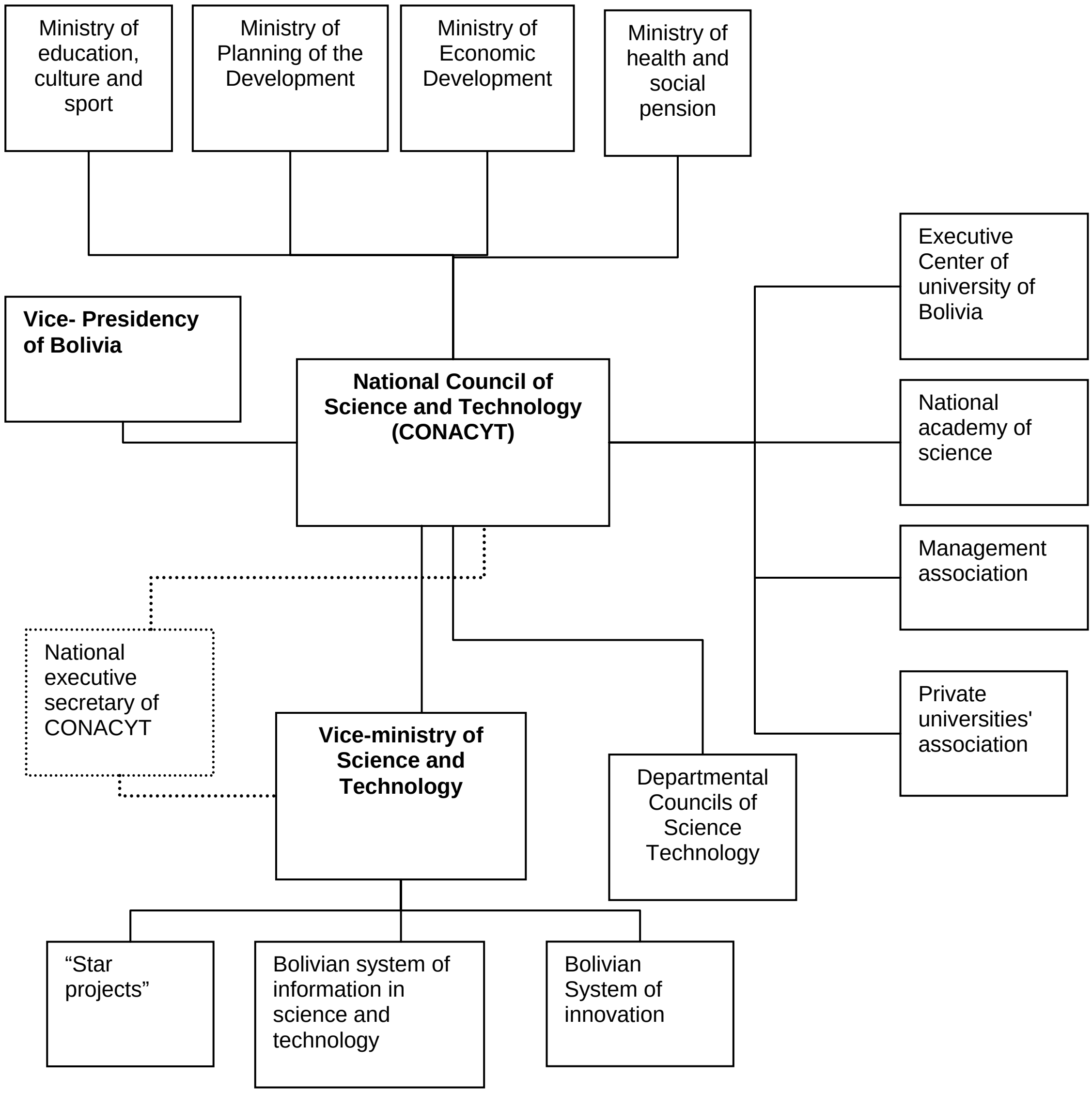
- The use of research to resolve the country's principal socio-economic problems (health, nutrition, education and housing)
- The funding of programs that help the formation of the National Science, Technology and Innovation System (SNCTI – acronym in Spanish) in the following areas: basic science and material sciences; social and human sciences, biodiversity, habitat and the environment; biotechnology; agricultural development; health; earth and ocean sciences; energy and mining; education studies
- The articulation and specialization of funding sources
- The provision of support for regional innovation strategies and the promotion of decentralization
- The creation of innovation networks
- The provision of support for small and medium businesses (Pymes – acronym in Spanish) in the stimulation of demand for innovation projects, technological development and modernization. The presence of Pymes, incubators and technological parks in regional development
- The provision of incentives for companies in technological development and innovation projects in conjunction with the academic sector via the subsidizing or partial cancellation of debt
- The creation of a National Observatory for Science, Technology and Innovation (S&T+I – acronym in Spanish) for the generation of indicators and prospective studies in the field

Another important consideration is the question of internationalization and cooperation in scientific activities for the development of human capital outside the country. Nevertheless, no strategies have been established to deal with the problem of a brain drain that, as is the case with other Latin American countries, has come to represent a recurrent problem due to political instability and the lack of resources for research.

EXAMPLE 6: BOLIVIA

Diagrammatic descriptor

Diagrammatic representation of science governance



Section 4: Knowledge and R&D performers

(Establishments/ Institutions/ Universities/NGO's)

<u>EXAMPLE 7: ALGERIA</u>

<u>Descriptors</u>

Number of public universities (14)	Université d'Alger Université Scientifique et Technique Houari Boumédienne (USTHB), Alger Oran Es Sénia Université des Sciences et de la Technologie d'Oran (USTO) Université Scientifique et Technique de Constantine (USTC) Université de Annaba Université de Sétif Université de Tizi Ouzou Université de Tlemcen Université de Batna Université de Blida, Université de Boumerdès Université Djillali Liabès, Sidi Bel Abbès Université de Béjaia
Number of private universities	No information
Colleges/ University centres (14)	Centre Universitaire de Tebessa Centre Universitaire de Biskra Centre Universitaire de Oum El Bouaghi Centre Universitaire de Guelma Centre Universitaire de Jijel Centre Universitaire de Skikda Centre Universitaire de Tiaret Centre Universitaire de Ouargla Centre Universitaire de M'sila Centre Universitaire de Médéa Centre Universitaire de Mostaganem Centre Universitaire de Béchar Centre Universitaire de Mascara Centre Universitaire de Saida
Number of internationally funded but locally based research institutes	No information
Government funded research centres (14)	Centre de Recherche en Astronomie Astrophysique et Géophysique, CRAAG Centre de Développement des Technologies Avancées, CDTA, Alger Centre de Développement des Techniques Nucléaires, CDTN Centre de Recherche et d'Exploitation des Matériaux, CREM Centre de Recherche Scientifique et Technique en Soudage et Contrôle (CSC), Alger

	Centre de Radio protection et Sûreté, CRS Centre de Développement des Energies Renouvelables, CDER Centre National des Techniques Spatiales, CNTS Centre de Recherche sur l'Information Scientifique et Technique, CERIST Centre de Recherche Scientifique et Technique en Analyses Physico-Chimiques, CRAPC, Alger Centre National de Recherche Appliquée en Parasismique, CGS Centre de Recherche en Economie Appliquée au Développement, CREAD Centre de Recherche en Anthropologie Sociale et Culturelle, CRASC Centre de recherche sur les Zones Arides
Private sector or corporate research institutes/centres (6)	Centre de Recherche-Développement de SONATRACH Centre de Recherche-Développement ANABIB Centre de Recherche-Développement SAIDAL Institut Algérien du Pétrole, rattaché en 1998 à SONATRACH, Centre d'Etudes et de Recherche Minière, EREM Centre de Recherche pour la Valorisation des Hydrocarbures et de leurs dérivés (CERHYD), intégré en 1998 au CRD Sonatrach,

Summary by field: There are 198 research institutions in Algeria today dependant on 16 different ministries.

Supervising department	**Number of structures**
Ministry for Higher Education and Scientific Research	60
Agriculture	73 (60 of which are experimental stations)
Industry, mining	20
Planning and infrastructure	3
Home Office	3
Health and Population	15
Public works	5
Telecommunications	1
Housing	4
Transport	2
Professional training	2
Work and social affairs	2
Youth and sports	1
Culture and tourism	5
Education	1
Religious affairs	1
TOTAL	198 research structures

EXAMPLE 8: COTE D'IVOIRE

Narratives

Description of strengths and weaknesses of the university system
Niche areas of research in the system and at universities
Nature of knowledge production undertaken in various sectors of the system

The university, the Centre National de Recherche Agronomique and the National Polytechnic Institute Houphouët Boigny are the three major R&D performers of the country. Since 1996, they all have evolved in different ways, each one experimenting with new ways of linking research and teaching and research and development.

Cocody University had tried to develop new relationships between research and teaching structures while integrating research centres to training units. This experiment has been contested in the country. It has been by far the oldest and the main university of the country. It has 13 research and training units, 12 research centres and institutes, 2 autonomous research centres and one school. In each unit, research activities are supervised by a scientific commission. The specificity of Cocody University is that some research institutes employ full time researchers. This is the case with the Centre Universitaire de Recherche Appliquée en Télédétection, which is integrated with the geosciences and mining resources unit and of the Centre National de Floristique. However, this organizational arrangement is not generally accepted. The academic community wants to keep a clear distinction between the different types of structures, especially concerning budget allocations. Indeed, this integration is seen as the first step towards a merging of the structures designed to compensate for the lack of human resources. Abobo Adjamé University is experimenting with a new type of recruitment. Academic staff no more belongs to civil service but signs a contract with the university.

The National Centre for Agronomic Research was created in 1998 after the merging of agronomic research institutes: the Institut des Forêts (forestry), the Institut des Savanes (savannah areas) and the Centre Ivoirien de Recherche Technologique. Its management introduces an interesting innovation: this centre has private status and a mixed capital: It is partly public (40%) and partly private (60%). The National Centre for Agronomic Research led a policy of privatisation of research much observed by Western and Central African countries interested in this kind of strategy. Researchers sign a contract with the institution, of which the general policy is to run according to the laws of economics. It is designed to adapt to the global market and to reinforce the relationships with private partners and development. Besides, the mixed capital will ease the Institute from the dependence upon public funding. It is managed by two structures: a General Assembly and a board of directors.

Section 5: Informal S&T structures

(Academies, Associations, Trade unions, Journals, etc = Scientific Community)

EXAMPLE 9: BURKINA FASO

Descriptors

Scientific journals in country (16)	**Publications depending on the CNRST** *"Revue Sciences et Technologies";* *"EUREKA!",* journal of popularisation; *"Série Colloques et Séminaires".* **Publications depending on the University** *"CEDRES-Etudes",* half-yearly journal of the Centre d'Etudes, de Documentation et de Recherche Economiques et Sociales of the FASEG; *"Résultats de la Recherche",* series, FASEG *"Documents de Travail",* series, FASEG *"Revue Burkinabè de Droit",* half-yearly journal of the FDSP *"Le Burkina Médical",* journal of the Société Médicale of the BFA (3 first issues financed by Presidential and Prime Minister Offices) *"Annales de l'Université: series "Sciences et Techniques"* *"Annales de l'Université: series "Lettres et Sciences Humaines"* **Regional publications (Western Africa) in Burkina Faso** *"Journal de la Société Ouest Africaine de Chimie"*, bulletin de la SOACHIM . *"Bulletin de l'OCCGE"*, bulletin de l'Organisation pour la Coordination et la Coopération pour la lutte contre les Grandes Endémies. *"Revue du CAMES: series Sciences et Médecine",* scientific journal of the Conseil Africain et Malgache pour l'Enseignement Supérieur. *"Revue du CAMES: series Sciences Sociales et Humaines",* scientific journal of the Conseil Africain et Malgache pour l'Enseignement Supérieur. *"Revue et Perspectives, Document de Travail ILRI/CIRDES"*, journal of both the International Livestock Research Institute (ILRI) and the Centre International de Recherche-développement sur l'Elevage en zones Subhumides (CIRDES). *"SUD Sciences et Technologies"*, Journal of the Ecole Inter-Etat d'Ingénieurs de l'Equipement Rural (EIER)
Scientific associations/societies (4)	SOACHIM, Société Ouest Africaine de Chimie, created in 1997. ABAO, Association des Botanistes d'Afrique de l'Ouest, created in 1997 Société Ouest Africaine de Gynécologie et d'Obstétrique. Société Africaine de Mathématiques.
Academies of science (1)	Académie des Sciences du Burkina Faso (to be established)

EXAMPLE 10: CAMEROUN

Narratives

Status of main journals (still being published or not)
(Historical) description of information structures

The scientific community in Cameroun emerged during the second half of the 1980s when national research was at its climax. Many scientific associations exist but barely survive because of a lack of funding: most members of the scientific community cannot contribute because they already have barely enough money to subsist. These associations originated many scientific journals that also have ceased publication for lack of funding. The majority of scientific and technical journals disappeared after the two first issues. Those which are running well are supported by foreign institutions.

Listing of some scientific journals in Cameroun

Revue Science et Technique (série Science de la Santé) published by the Institut de Recherches Médicales et d'Etudes des Plantes Médicinales (IMPM), the last issue appeared in 1990.

Revue Science et Technique (série Science de la Terre) published by the Institut de Recherches Géologiques et Minières (IRGM), the last issue appeared in 1990.

Revue Science et Technique (série Sciences Agronomiques et Zootechniques) published by the Institut de Recherche Agricole pour le Développement (IRAD) the last issue came out in 1990.

University of Yaoundé I

Revue de Biosciences (Quarterly journal ; Vol 7 n°2 et 3 published in 1990.)

Annals of the Faculté des Sciences : série Science de la Terre

Academic Annals of the Sciences de la Santé

Conseil Phytosanitaire Inter africain / Organisation de l'Union Africaine[130]

Revue africaine de protection des plantes N°1 published in 1993.

Ecole Normale Supérieure

Journal : *le Savoir*

Dschang University

Journals : *Sciences Agronomiques et Développement*

Le Germoir

Revue des Productions animales du Cameroun (N°1 paru en 1991. N°3 paru en 1995)

Association Camerounaise des Biosciences

Cameroon Journal of Biological and Biochemical Sciences

Comité National de Géographie du Cameroun

Bulletin de liaison

Réseau du Programme '' Arbres forêts et Communautés Rurales''

Special issue (15 et 16), déc. 1998

MINREST (IRAD, Herbier National)

Flore du Cameroun ; 105 familles décrites et publiées dans 32 fascicules

[130] Published by the Secrétariat Scientifique du Conseil Phytosanitaire Inter africain de la Commission Scientifique, Technique et de la Recherche of the Organisation de l'Unité Africaine, based in Yaoundé.

Programme TROPENBOS Cameroun (PTC), Directeur : Dr P. Schmidt

TAM TAM : Bulletin trimestriel d'information n°3 paru en février 2000, publié avec la collaboration de l'IRAD et de l'ONADEF.

Revue de la Médecine Hospitalière au Cameroun

Association Camerounaise des Médecins

Journal du Médecin

Listing of some other scientific associations

National associations

Association des Mathématiciens Camerounais (exists but is not active)

Carrefour des Géographes (exists but is not active)

Société de Cardiologie (very irregular running)

International associations

Association des Géologues et Géographes Docteurs des Universités Françaises (French support)

Observatoire du Changement et de l'Innovation Sociale au Cameroun (research network originated by a researcher in the Insitut de Recherche pour le Développement)

Regional associations

Groupe Inter Africain de Recherche et d'Analyse en Géométrie Appliquée (Benin, Cameroon)

Réseau Inter-Africain d'Etudes Urbaines (research network currently inactive because of the different conflicts in Central Africa).

Section 6: S&T Human Resources (Description/statistics + Considerations about the Profession of researcher: status, salaries, etc)

EXAMPLE 11: ARGENTINA

Indicators

Number of researchers/ scientists in country	36,167 (2003)
Number of academics in HE institutions	N/a
Number of PhD students	7,442 (2003)
Number of researchers per million of labour force	980
Nr of academics by scientific field	Cf. Table below
Nr of academics (gender breakdown)	N/a
Number of academics in HE institutions per million of labour force	N/a
Nr of Masters and Doctoral students (enrolments) * gender	N/a
Nr of M and D students by field of study (6)	N/a

Researchers by field

	1999	**2000**	**2001**	**2002**	**2003**	**2005**[1]
Natural Sciences	25.8%	28.8%	30.1%	29.8%	29.4%	27.8%
Engineering and Technologies	19.6%	19.3%	19.3%	18.1%	17.5%	17.5%
Medical Sciences	15.0%	13.1%	12.0%	12.9%	13.4%	14.1%
Agro Sciences	13.3%	11.8%	11.0%	11.4%	11.6%	13.0%
Social Sciences and humanities	15.3%	15.0%	16.4%	17.8%	18.4%	18.4%
Humanities	11.1%	12.1%	11.3%	10.0%	9.7%	9.2%
	32,583	**35,015**	**33,738**	**34,796**	**36,167**	**No info**

EXAMPLE 12: CAMEROON

Narratives

Profession and status of academics and knowledge workers
Scientific mobility and brain drain challenges

The beginning of the 1980s was the golden era for Cameroonian researchers, their salaries were comparable to French researchers' ones. The elaboration of a specific status for researchers signed in July 1980 also attracted many people to the profession. Some correspondences between the grades of teacher-researchers at university and full-time researchers were provided for facilitating exchanges and maximising the good use of human resources. This major step led to the great increase in the number of researchers in the 1980s. Furthermore, it acknowledged the existence of a community. A new status of researcher developed and provided for a greater harmonisation of the grades at university and outside.

The economic crisis led to a halt in financial support of research institutes and a catastrophic decrease in subsidies to the academic world but also caused a dramatic reduction in the amount of researchers' salaries so that since this time they have got to find extra resources they usually would get with consultancy work for foreign NGOs or financial backers. This critical situation gets researchers and authorities to look for different types of research structures and activities. Three steps can be defined in the evolution of salaries: before 1993 and the decrease for salaries of civil servants, after that decision and after 2003 when the state raised salaries again.

Consequently, many researchers left their jobs. Those who staid are often demotivated. However, those who left rarely emigrated (in 30 years out of 60 researchers supported by the International Foundation for Science, only one of them immigrated into the USA when he retired). They prefer finding another job in their country in both public and private sector. Others keep their job but try to find other resources while doing consultancy or teaching in the whole continent (even if 8000 graded students were unemployed in 2000, Cameroonian degrees are internationally acknowledged as good ones and Cameroonian teachers and researchers are in high demand). If they still cannot feed the whole family, another member of the family works as a taxi driver or a farmer, etc. Besides, national researchers do not enjoy a great social position.

There are few women involved in research in Cameroon. In 1999, they were 18 out of 204 researchers in the Institut de Recherché Agricole pour le Développement i.e. 8.9 %, in 2006 they represented 13.5% of the IRAD research force. In 1997/1998 in sciences faculties, there were 29 women out of 214 teachers (13.5%).

Research is often mentioned in the press and the media. Scientific Conferences are introduced, experts are asked during a spectacular event; there are scientific programmes broadcasted on the radio and journals of scientific popularization. Communication has been one of the principal goals of the Ministry. It is embodied by the National Programme of Research and Agricultural Popularization recently implemented.

Section 7 Research Funding (Public or private; National and international; Trends)

EXAMPLE 13: ECUADOR

Indicators

R&D intensity (GERD/GDP)	0.7% (2003)
Expenditure on R&D per researcher	$22.00
Expenditure by sector	Cf. Table 1 below
Source of funding (incl. overseas agencies) – actual values and proportions	No info
Expenditure by scientific field (6)	Cf. Table 2 below

Table 1 Expenditures in S&T activities and GDP by sector.(percentages) 1996-2000

Executor Agent	1996	1997	1998	1999	2000
Universities	23.6	21.7	25.9	23.2	45.8
Enterprises	5.7	4.4	5	-	-
Non lucrative organizations	34.9	34.5	31.1	19.5	20.7
Public Institutions	35.9	39.4	38	57.2	33.6
Total	100	100	100	100	100
GDP (%)	0.18	0.23	0.22	0.19	0.19

Source: FUNDACYT

Table 2: S&T expenditure by field (Thousands USD$) 2001-2003

Scientific Area	2001		2002		2003	
	Mill U$	%	Mill U$	%	Mill U$	%
Natural sciences	3.146	25.0	3.057	19.3	4.469	24
Engineering and Technology	4.027	32.0	5.148	32.5	6.089	32.7
Medical sciences	802	6.4	1.156	7.3	1.620	8.7
Agriculture	3.309	26.3	4.80	30.3	4.73	25.4
Social sciences	1.145	9.1	1.584	10	1.657	8.9
Humanities	96	0.8	79	0.5	71	0.48
Total	12.583	100	15.841	100	18.621	100

Source: FUNDACYT

EXAMPLE 14: CAMEROON

Narratives (Example: Cameroun)

Role of government and other domestic agencies in funding research
Role of international donor and funding agencies in funding and steering research in the country

Cameroonian research benefited from important state support until the middle of the 1980s. In 1974 and with the creation of the ONAREST, Cameroon was one of African States that invested most in research. This was possible because of a levy on oil revenues but also because of state involvement in the establishment of a scientific elite. Agricultural research, which constituted one of the most dynamic sectors, flourished with the aid of public funds. The Institut de Recherche Agricole and the Institut de Recherche Zoologique et Vétérinaire were the two principal institutions for agricultural research.

Operating budget and equipment grants of the IRA and the IRZV from 1976 to 1986 (million FCFA)

Years	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86
IRA	982	889	820	1,298	1,486	2,073	3,344	4,481	5,32	5,913
IRZV	77	126	203	281	572	1,282	1,526	1,83	2,642	3,314
Total	1,059	1,015	1,023	1,579	2,058	3,355	4870	6,311	7,962	9,227

Operating budget and equipment grants of the IRA and the IRZV from 1986 to 1993 (Million FCFA)

Years	86/87	87/88	88/89	89/90	90/91	91/92	92/93
IRA	3,216	2,164	2,128	2,373	1,849	1,349	371
IRZV	2,027	2,108	1,616	2,251	2,076	2,011	1,985
Total	5,243	4,272	3,744	4,624	3,925	3,36	2,356

In addition, both institutions earned money from the sales of vegetable and animal production and also provision of expertise. The investment in agricultural research also concerned the large areas committed to the Institut de Recherche Agricole (4,871 hectares) and the Institut de Recherche Zootechnique (10,502 hectares) as experimentation sites.

Funding and staff growth stopped brutally because of the economic crisis in 1986. No more teacher or researcher would be recruited for a long time, salaries would not be assured and programmes would not be financed any more. The transfer of the management of salaries to the Chancellor of the Exchequer was designed to stop the haemorrhage but it brought no result. During the most difficult years from 1990 to 1996, every research programme performed with public funds was stopped. Only those financed by external organisations continued but with much uncertainty around salaries. Universities and research institutes were affected by this halt of financing and recruitment: total funding allocated to universities decreased by a factor of ten between 1991 and 1999. The short increase in the academic budget in 1998 did not compensate for the increase in student numbers.

Budget per student from 1991 to 1999

Years	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Student numbers	45,000	43,755	38,426	40,080	38,145	36,674	49,265	60,534
Budget	49,756	21,477	13,08	17,100	8,075	5,765	5,349	7,052

Years	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Budget/Student	1.11	0.49	0.34	0.43	0.21	0.16	0.11	0.11

Besides, this money was allocated to operating budget and not investment budget and the free management of global funding by the institutions tended to disadvantage research activities which are not highly visible. Conscious of that situation, the government decided to dedicate a specific budget to each research programme, a budget managed by boards of directors. However, funding has been very irregular and credits officially allocated are not always effective. Even in 1998 and 1999 when GDP grew by 5 per cent, no significant growth appeared in research funding.

In the 1990's international funding became indispensable to research activity in Cameroon. Before 1987, 85% and sometimes 95% (salaries included) of research funding was assured by the state, a proportion that fell down to 61% between 1987 and 1993. Political tensions worsened the situation: at a national level, the Institut des Sciences Humaines was dissolved _ only the centre for research on cartography survived becoming the Institut National de Cartographie. At an international level, the contested re-election of the president in 1993 led some financial backers, such as the USAID to put an end to their cooperation with Cameroon.

Evolution of external funding allocated to the IRA and the IRZV (million FCFA)

Years	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**Total**
International Centre for Research on Agroforestry	115.9							115.9
Prêt BIRD	4,969			285	891			6,145
Donation ODA (now DFID)	1,210							1,210
Donation GTZ (Germany)	1,151							1,151
Loan from the Caisse Centrale de Coopération Economique	/	1,250		32	110			1,392
Donation Fonds d'Aide à la Coopération	/	750		12	42,5	100		904.5
USAID (US)	/				4,000			4,000
STABEX	/					115		115
FED	/					188	2,140	2,328
Scotland university	/			20				20
GATSBY	/			26				26
CEE	/			12	16	250		278
IITA	/			46				46
CIRAD	/		1.5					1.5
OUA	/				1			1
Purdue university/USA	/				1.1			1.1
Alabama university	/	0.6						0.6

Belgium	20							20
TOTAL	7,465.9	2	1,5	433	5,061.6	653	2,14	17,755.6

Section 8 Research Output (post-graduates/ publications/ papers/ patents)

EXAMPLE 15: SRI LANKA

Indicators and narrative

Total output in ISI-journals (by scientific field)	
Total output in local journals (by field)	
Nr of Masters and Doctoral graduates	
Nr of PG theses/dissertations	
Nr of patents	

Table 1: Total undergraduate enrolment and graduate output (1995-2003)

S & T fields	Year	Total Enrolment	Graduate Output
Science	1995	5257	844
	2001	7916	1052
	2003	8588	na
Agriculture	1995	1365	226
	2001	2351	365
	2003	2658	na
Engineering	1995	2703	458
	2001	4324	653
	2003	5073	na
Architecture & QS	1995	331	56
	2001	347	79
	2003	513	na
Medicine	1995	4314	442
	2001	5355	801
	2003	6484	na
Dental Science	1995	424	66
	2001	433	71
	2003	430	na
Veterinary Science	1995	298	37
	2001	373	70
	2003	569	na

Source: University Grants Commission, Colombo (2003).Na=not available

There has been an increase in the growth of enrolment for postgraduate degrees in the S&T sector locally (Table 2). The premier funding institutions for S&T in Sri Lanka, such as the National Science Foundation, play a key role in funding higher degrees (17%) up to PhD level (local) through research projects in all fields of science and technology (Samarajeewa, 2003). The other funding agencies which promote postgraduate degrees in Sri Lanka are the Council for Agricultural Research Policy (CARP) and the National Research Council (NRC).

Table 2: Growth of Enrolment of Postgraduate Students in Universities 1999-2003

Year	Science	Agric	Engineering	Architect	Medicine	Dental	Vet	Total
1999	181	0	115	76	102	2	0	476
2000	185	30	80	108	6	2	2	413
2001	286	55	168	0	14	0	0	523
2002	350	61	313	98	39	1	4	866
2003	439	41	**	27	43	1	1	584

Source: Sri Lanka University Year Book 2003/2004, University Grants Commission, Colombo,

** not available at the time of Survey

Compared to the number of postgraduate holders in the scientific community in Sri Lanka, the university community having postgraduate degrees is significantly higher (Table 10). This is because the university staff has to complete a postgraduate degree within a given period during their tenure and also they have more opportunities for foreign and local scholarships compared to non-academic scientists. It has also been noted that over years, the trend of research publication output by the universities is higher compared to the local research institutes attributing to the fact that the capability of conducting independent and quality research increases with more faculty getting PhDs. According to the figures of research publications appearing in the Science Citation Index for Sri Lanka in the year 2000, the universities had published 128 papers compared to the 78 papers published by the research institutes.

Table 3: Number of S&T postgraduate degree holders in the scientific community

Institute	MSc/Mphil *	PhD	MD	Total
Universities	295	719	68	1082
R&D Institutes	283	180	-	463
Total	578	899	68	1545

Source: Samarajeewa (2003). **Note**: These degrees represent the fields of science, engineering, architecture, agriculture, medical sciences (MD) including dental and veterinary sciences. * by research

Compared to R&D institutes, the university sector in Sri Lanka has been able to increase its research base mainly due to considerable increase in faculty numbers along with the post-graduate students (PGs), particularly in science and engineering during the last few years. As Table 9 shows, science PGs increased from 181 in 1999 to 439; and engineering PGs increased from 115 to 313 during 1999 and 2002-03. Also, out of 899 Ph.Ds, university sector accounts for 80% and the rest by R&D institutes. To this, one may add 68 professionals with PG degrees in medicine (Table 10). Besides, the production of postgraduates, especially the doctoral degree holders who could conduct research independently and also operate professionally at an international science level constitute a significant research base of Sri Lankan universities currently as shown in the Table 11.

Table 4: International publications (S&T fields) from Sri Lankan universities and R&D institutes 2000-2005

Universities	Publications	R&D Institutes	Publications
UniversityPeradeniya	142	Inst. of Fundamental Studies	77
University Colombo	82	Industrial Technology Institute	9
University of Kelaniya	29	Coconut Res. Institute	7
University of Ruhuna	21	Rubber Res. Inst	7
University of Sri J'pura	19	Nat.Hosp. ; & Fac. Medicine	6
University of Moratuwa	17	Internat. Collaborative papers	40
Total	310	Total	146

Source: ** SCI data base through (http:/ra01.isiknowledge.com/analyze/ra.cgi)

The comparative strength between university sector and R&D institutes is also revealed by the R&D output counted in terms of international publications as shown in Table 4 for the period 2000 to 2005 in all fields of S&T for Sri Lanka as found in the Science Citation Index (SCI) database. Given the increase in S&T human resource base in the university sector, it clearly dominates over R&D institutes in terms of research output. The universities, which have registered more than 300 international publications for period 2000 to 2005 viz., Universities of Peradeniya (142); Colombo (82); and Kelaniya (29) etc. The R&D institutes, which have been able to maintain comparable research output for the above period are the Institute of Fundamental Studies with 77 publications and International Water Management Institute with 39 (not given in the table) publications.

In the case of Sri Lanka, the pattern of publications can be seen mainly at three levels; the publications listed in the Science Citation Index (SCI); the publications in all refereed journals (local and international) other than those listed in the SCI; and the communications presented at the Annual Sessions of Sri Lanka Association for the Advancement of Science (SLAAS). The number of annual SLAAS publications in different S&T fields has varied between 250 and 400 from 1999-2004 (Table 5).

Table 5: SLAAS publications by subject areas (1999-2004)

Field	1999	2000	2001	2002	2003	2004
Medical, dental and vet. sciences	28	52	25	28	26	31
Agricultural science and forestry	86	102	85	97	87	97
Engineering sciences	40	24	45	59	24	26
Life and earth sciences	49	64	51	88	37	45
Physical sciences	37	43	20	38	21	26

Chemical sciences	32	49	27	55	34	22
Social sciences	28	31	27	33	28	39
Total	**300**	**365**	**280**	**398**	**257**	**286**

Source: SLAAS, Colombo Source: National Survey on R&D (2000), National Science Foundation, Colombo.

Table 6: International publications by subject areas (1994-2000) Field

Scientific field	1994	1995	1996	2000	2004**	Total
Medical science	54	46	23	65	60	248
Veterinary science	09	02	09	05	na	25
Biological science	19	10	05	32	31@	97
Physical sciences	05	03	08	14	20	50
Chemical sciences	09	24	17	20	24@@	94
Engineering science	07	07	05	09	18#	46
Agriculture	15	16	12	17	30	90
Fisheries, aquatic sci. & water resources	01	01	08	02	20*	32
Environmental Sciences	na	na	na	na	24	24
Total	120	109	87	164	227	724

** SCI database through (http:/ra01.isiknowledge.com/analyze/ra.cgi)

*Water resources mainly; @includes 9 ecology publications; @@includes material sciences and Interdisciplinary; #includes environmental and electrical/electronic engineering

According to the available data as indicated in the Table 6, it is interesting to note that up to the year 2005, a majority of S&T publications at the international level has been in the fields of medical, biological, chemical, physical, agricultural and engineering fields. The data also show that the number of international publications by subject areas has increased only by 25-35% over a period of six years from 1994 to 2000; and by 38% between 2000 and 2005. However, according to the R&D Survey conducted by the National Science Foundation, Sri Lanka, technology related research such as food technology, industries, information technology etc. figured in the papers published locally in 2000 (Table 7). With low level of R&D funding even though some universities and R&D institutes maintained some presence in science at the international level, the S&T indicators as shown in various tables reveal a picture of relative stagnation or even decline of R&D effort over the last fifteen years.

Table 7: Distribution of locally published research papers in the year 2000

	Number			Number	
Agriculture	167	21.6	Biological Sciences	37	4.8
Biotechnology	24	3.1	Chemical Sciences	58	7.5
Earth Sciences	3	0.4	Education	1	0.1
Energy	15	1.9	Engineering & Tech.	172	22.3
Environmental Sci.	27	3.5	Fisheries & Aqua. Sci.	21	2.7
Food Science	29	3.8	Information Tech.	9	1.2
Mathematics	7	0.9	Health Sciences	111	14.4
Natural Sciences	41	5.3	Physics	28	3.6
Veterinary Science	7	0.9	Forestry	7	0.9
Industries	8	1.0			

Source: National Science Foundation, Colombo (2000)- (unpublished data).

The first record of patent in Sri Lanka is in 1982. However, the growth pattern of patent grants over the period 1990s- 2000s shows an increasing interest of Sri Lankan scientists and technologists on the economic significance of intellectual property protection (Amaradasa *et al,* 2002). According to the NSF Survey (Amaradasa *et al*., 2002), another observation made was that the smaller contribution of patents both by commercial organizations (22%) and by public research institutes (6%), as compared to the contribution of 72% by individual inventors, was a reflection of the weak innovative character of the organized sector. The research institutes in Sri Lanka to date have developed 147 new technologies of which 95 have been commercialized and 20 such technologies developed have been patented.

EXAMPLE 16: ARGENTINA

Narrative

Description of specific policies (funding, incentive) and initiatives to encourage research publications locally and internationally

For the evaluation of scientific production in Argentina country two of the most commonly used indicators are patent applications and other intellectual property titles, as well as the participation of the national scientific community in the publication of articles in peer-reviewed magazines.

Analysis of patent applications over the last five years demonstrates that the downward trend that persisted from 2002 has now been reversed. In 2005 a 5269[131] patent applications were lodged which situates Argentina in second place, behind Brazil, on the table of countries registering patent applications at the regional level. Statistics for the relation between patents applied for by resident scientists, researchers, and those applied for by non-residents demonstrate that residents made 1054 applications and non-residents 4125. This indicates a rate of dependence (non-resident patents/resident patents) of 3.9. With respect to the fields in which patents are applied for, 40.8% are

131 Indicadores de Ciencia Y Tecnología (Science and Technology Indicators). Argentina, 2005, SECYT.

in the field of engineering and technology, 36.3% in exact and natural sciences, 17.6% in medical science and 3% in agriculture, with the participation of the remaining fields being less than one.

The participation of the Argentinean scientific community in the SCI has remained constant with only small variations over the last five years. In 2005 5698, articles were published. The distribution of the production of these articles by areas of knowledge demonstrates that the most productive area is physics, chemistry and earth sciences with 34%, followed by life sciences with 27.9%, agriculture, biology and the environment with 20.8%, clinical medicine with 23.4%, engineering, computing and technology with 6.1%, the social and behavioural sciences with 2.6%, and the remaining areas with participation of less than 1%. This demonstrates that no direct relation exists in the performance of the different areas of knowledge between the number of publications and the number of researchers. At the regional level, in absolute numbers, Argentina is situated behind only Brazil and Mexico for the number of articles published in SCI.

Also of note is the production of publications in S&T, maintaining Argentina's publishing tradition. In 2005, 2,165 books on the subject of science and technology were published while the science and technology bodies publish 876 magazines. The majority of these magazines are produced by the public universities. Nevertheless, it has been noted that these publications are low profile and suffer from budget problems that limit their distribution. The CONICET is implementing a series of programs for the support of those magazines with the highest editorial quality and content using international evaluation criteria through the creation of a basic nucleus of publications for which they are developing different calls for proposals. Another strategy is the creation of Scielo (Scientific Electronic Library Online), an electronic library consisting of complete texts, a database and system of indicators that offers visibility and easy access to Argentina's scientific production. There are also plans to extend the program to other countries.

Section 9 Scientific co-operation and agreements

(Description: formal agreements; main partners (measure through bibliometrics); doctrines, practices and evolution; types and amount of funding – if available). Local collaborations (scientific and socio-economic).

Example 17: Jordan

Descriptors

Nr of bilateral scientific agreements	5
Nr of multilateral and regional agreements	1
Nr of international agencies operating in country	

Jordan has signed international cooperation agreements either under the Ministry of Planning and International cooperation, or the Higher council or the universities directly. The Ministry of Planning was established by law in 1984 as a substitute body for the national Council for Planning. Its mandate includes increasing the Gross Domestic Product growth rate; reducing the rate of poverty and unemployment; attaining development equilibrium among various districts and governorates; and developing efficiency and effectiveness in public sector performance.

The Table below lists the international S&T agreements/MoUs/Programmes/projects that Jordan is engaged in through the Ministry of Planning and International Cooperation.

International S&T Cooperation via the Ministry of Planning and International Cooperation (MoPIC)

Initiative	Foreign Party	Jordanian Counterpart	Starting Date	Duration	Areas of Cooperation	Budget
Trans-European Mobility Scheme for University Students (TEMPUS)	EU	Ministry of Higher Education (EMPUS National Office)	2003	5 Years	Higher Education	6 Million Euro
MoU on S&T Cooperation	Pakistan	HCST	2001	5 Years	S&T Fields across the board	NA
Agreement on Cultural and Technical Cooperation	Italy	MoPIC	1999	Open	Enhancing Education and S&T	NA
Agreement on S&T Cooperation	Croatia	MoPIC	2004	5 Years	S&T Fields across the board	NA
Agreement on S&T Cooperation	Congo	MoPIC	2002	5 Years	S&T Fields across the board	NA
Grant Agreement to establish IT Incubator in Jordan	USA	HCST	2006		IT and SMEs Development	256,000 $US

The Higher Council for Science and Technology places great emphasis on the significance of S&T cooperation due to the beneficial impact that it has on the exchange of information and transfer of knowledge and technology. To this end the Higher Council is signatory to many cooperation agreements with Arab and international bodies. Many of these culminate in joint projects that assist in the development of S&T capacities (see annex for a detailed list of the cooperation agreements of the Higher Council).

Example 18: Costa Rica

One of the strategies proposed by Costa Rica is the maximization of cooperation with other countries and multilateral organizations. The MICIT is responsible for organizing these actions. International cooperation is analyzed in three groups: bilateral cooperation (with countries), multilateral cooperation and participation in International Cooperation Networks.

Bilateral accords exist with Germany, Argentina, Brazil, Canada, Taiwan, South Korea, Denmark, Spain, France, the United Kingdom, Rumania, the Russian Federation, Holland, Israel, Italy, Japan, Mexico, Norway, Sweden, Switzerland and Venezuela. Although the accords with different countries include different types of activity, generally they include support for the training of human resources and, in the case of developed countries, financial support in concrete thematic areas.

With respect to multilateral organizations, Costa Rica is engaged in joint activities with:

- The Central American Bank for Economic Integration,
- The International Reconstruction and Promotion Bank,
- The Organization of American States,
- The International Atomic Energy Organization,
- The International Organization for Migration (IOM),
- The Latin American Faculty of Social Sciences,
- The International Labour Organization,
- The Latin American Economic System,
- The Inter-American Agricultural Cooperation Institute,
- The Tropical Agriculture Research and Training Centre,
- The United Nations Educational, Scientific and Cultural Organization (UNESCO),
- The United Nations Organization for Agriculture and Food (FAO),
- The United Nations Development Program (UNDP), and
- The European Union.

Costa Rica also participates in various cooperation networks and programs. With respect to International Cooperation Networks the most important are:

- The Latin American Science and Technology Indicators Network (RICYT – Spanish acronym),
- The Caribbean Energy Information System (CEIS),
- The Network for the Popularization of Science and Technology in Latin America and the Caribbean,
- The Network of Postgraduate Studies in Planning and Management of Science and Technology in Latin America,
- The Central America and Panama Commission for Science and Technology Policy Development (CTCAP – Spanish acronym),
- The Latin American Biological Science Network (RELAB – Spanish acronym),
- The Latin American Mathematics Network (UMALCA – Spanish acronym),
- The Latin American Physics Network (RELAFI – Spanish acronym),
- The Latin American Astronomy Network (RELAA – Spanish acronym),
- The Latin American Biotechnology Network,

- The Regional Biotechnology Program for Latin America and the Caribbean (PRB – Spanish acronym),
- The Latin American Botanical Network (RLB – Spanish acronym), and
- The Caribbean Academy of Science.

Costa Rica also participates in the following Science and Technology Cooperation Programs:

- The Latin American Science and Technology Development Program (CYTED - Spanish acronym),
- The Science and Technology Common Market Program (MERCOCYT – Spanish acronym);
- The group of Environmental Cooperation Programs and Networks: The Coastal Regions and Small Islands Environmental and Development Program (CSI – Spanish acronym),
- The Earth System Research,
- The International Framework, the International Biodiversity Program (DIVERSITAS),
- The Sustainable Development Networks Program (SDNP – Spanish acronym),
- The Ecological Sciences Program (MAB – Spanish acronym),
- The Caribbean Coastal Marine Productivity Program (CARICOMP), and
- The Scientific Committee on Oceanic Research (SCOR).

Of particular relevance are the Agriculture and Biotechnology Sciences Cooperation Programs and Networks such as:

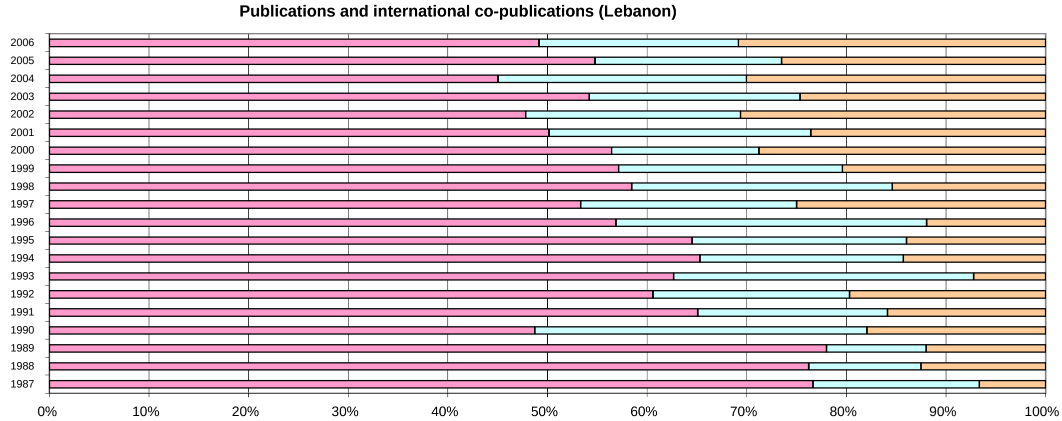
- The Tropical Agriculture Centre for Research and Training (CATIE – Spanish acronym),
- The International Centre for Tropical Agriculture (CIAT – Spanish acronym),
- The Inter-American Institute for Agricultural Cooperation (IICA – Spanish acronym),
- The Biotechnology Sub-Program of the Latin American Science and Technology for Development Program (CYTED Spanish acronym),
- The System of Specialized Information in Food Biotechnology and Technology for Latin America and the Caribbean, and
- The International Centre for Genetic Engineering and Biotechnology (ICGEB).

Degree of scientific collaboration as measured through share of foreign co-authors of papers	Decline from 75% in the late 1980s to about 50% in 2006

Example 19: Lebanon

The current ratio of the international co-publications to the total number of publications in Lebanon is slightly above the average level for “other countries” mentioned above (see Figure 11).

Figure 11: Relative share of publications and international co-publications in Lebanon (1987-2006)



	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
With EU	6	10	6	7	10	13	6	14	13	13	45	30	50	76	71	91	85	112	120	131
Without EU	15	9	5	13	12	13	25	20	20	34	39	51	55	39	79	64	73	93	85	85
Lebanon only	69	61	39	19	41	40	52	64	60	62	96	114	140	149	151	142	187	168	248	209

Thomson scientific data, P.L. Rossi/IRD computing

The internationalisation of Lebanese scientific production has decreased significantly, the high being 75% in the late 1980s, the last years of the civil war when international collaboration was essential to survival (see Figure 8) to around 50% today. In 2004, medical research was the discipline that had the lowest percentage of international co-publications (38.6%); chemistry (68.2%) and physics (72.6%) had the highest. The share of international co-publications highlights the increasing participation of Europe (from around 10% in the late 1980s to slightly above 30% in 2006)

Narratives

Main international and regional scientific partners

Main institutional collaborators

Domains and topics of scientific research

Example 20: Bahrain

The Bahrain Centre for Studies & Research (BCSR) participates in several GCC scientific cooperation activities with universities, institutes, research establishments and specialized regional organizations. The Centre also cooperates through contractual and joint research projects, through the exchange of experts, visits, scientific publications and information sharing. BCSR also participates in the organization of scientific conferences, workshops and training programs.

BCSR has ties of cooperation with distinguished international scientific organizations and institutions through the recruitment of experienced and renowned scientific consultants to provide Bahraini researchers with scientific consultancy and technical support; in addition, BCSR participates in scientific conferences, workshops and training programs.

BCSR has signed memoranda of understanding and scientific cooperation agreements with the following research centres:

- The Royal Scientific Society of the Hashemite Kingdom of Jordan.
- Ministry of Scientific Research Affairs in the Arab Republic of Egypt.

- The Arab Institute for Planning in Kuwait.
- China Centre for Contemporary World Studies and Research in the People's Republic of China.
- The Political and International Studies Institute in the Islamic Republic of Iran.
- The National Academy for Sciences, Republic of Belarus.
- The Gulf Research Centre, Dubai.
- The Strategic Studies Centre, the Republic of Turkey.

4.3 CONDUCTING COUNTRY STUDIES

Our final section in this Report is devoted to a discussion of how the template, which has been outlined and illustrated in the previous two sections, could be used in country studies. We believe that the nature of the template as proposed have a number of methodological as well as “organizational” implications that need to be spelt out. We begin with the former.

4.3.1 Methodological considerations

<u>Some reflections on indicators</u>

Although it is often recognized and admitted that standard science and technology indicators are limited in various ways, many agencies and governments continue to use them uncritically. More than 20 years ago, Martin and Katz[132] in a classic research evaluation study made the important point that most S&T indicators are at best “partial” indicators and do not necessarily capture the true meaning of the underlying constructs. More recently, Godin and his colleagues have also reminded us that most of the existing indicators only capture input and output factors of science systems and say very little if anything about the utility, value or impact of science on society[133]. The core constructs of science and technology – the nature of science, scientific capability and capacity, the intensity of research expenditure, knowledge production and research output to mention a few – are not easily reducible to single indicators or even more complex indices.

In fact one could easily show that some of the classic indicators may be misleading especially about the status of science in a country. Most of the standard indicators do not tell us anything about qualitative issues: how science is perceived or experienced in a country; whether science is valued or not by a government; whether the profession or status of the scientist is changing, being nurtured, downplayed or disregarded as unimportant. Indicators about flows of money from external donors do not necessarily tell us how such donors might affect the mode of knowledge production, the forms of accountability or how research agenda’s are steered and shaped by such funds. Many more examples can be given.

The same applies to indicators that are found in the field of Higher Education. Some indicators are interesting when they provide information on the profession of the researcher or scientists (and the conditions of scientific production). But this is indirect, and generally limited to academics, gross enrolment in tertiary education, number of students per academic; number of academics (permanent employees), time devoted to research (which remains an ongoing issue of contestation), proportion of academics with PhDs, and so on. Again, even very basic descriptive information on the history of education in a country, a

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[132] Ben Martin ….
[133] Benoit Godin

chronology of the growth of universities, descriptions of relevant policies and initiatives are more illuminating.

The same applies to the size of the research work force. In many of the countries reviewed in our study it was impossible to gather separate information about academics and other scientists in the science system. Effort to specify the number of researchers (and engineers but not others) in the Research centres of each ministry or government department were only partially successful. Even if these basic data would be available it would augment current standard indicators.

In summary then: Our point of departure in this study has been based on the following assumptions:

- Existing standard S&T indicators (including bibliometric indicators which are not always included) are in general terms insufficient to provide a truthful picture of the science system of the country.
- Added to the previous point is another obvious one: the majority of the countries that we have reviewed do not even gather reliable data on these indicators in a regular fashion.
- It is therefore important to think creatively about new indicators which can help shed light on key features of S&T systems; and
- In the final analysis – and this is a key feature of the template produced here – the best statistical indicators have to be complemented by additional descriptive and qualitative information.

<u>The need for “monographic studies”</u>

We strongly believe that good practice in conducting country studies would involve what could be termed <u>monographic</u> studies of research. The template for such studies has been outlined in the sections above.

The purpose is threefold:

- Obtain sound and reliable data on key <u>indicators</u> (credible size: budgets and their components [sources, uses]; staff (by sector, maybe by establishment: permanent, part time, and if possible: with which status and which qualification…);
- Produce relevant <u>descriptors</u>, especially about:
  - The status of the profession (payment and careers: state of things and chronology; comparison with other trades; difference between academics and staff of research Centres);
  - The chronology of research institutions: main establishments and key figures, authorities and organizational charts, coordinating bodies and their

influence; scientific bodies (Academies, assessment commissions, Congresses, Journals and their influence);
    - The (chronology of) budgets and their sharing out;
- Create narratives, illuminating the previous data, about i.e: The profession: which part of the academics (of "researchers") are carrying out research? Have they parallel activities (which sort)? Careers and incentives to research. What are the opportunities to collaborate with other scientists (local and foreign) or with local clients (productive and social sectors, authorities…) ? What for ? How are they built ? The working conditions: equipment, maintenance, documentation, travels, sabbaticals and training periods, upgrading ? The management of institutions.

We would also suggest that any such monographic studies would include a questionnaire survey component. Questionnaires to the staff at key research performing institutions provide one with some standardized but first-hand information that is not easily gathered in other ways. Such a practice (cf Morocco) has proved very efficient in gathering sound information about the number of research teams, their size and structure; the nature and condition of the equipment and the practical ways to keep it in good repair; the access to scientific information; collaborations (nature, sustainability, partners: foreign and local, for science or development), operating budgets, networking, and the handicaps to the activity perceived as most serious (or not).

Such data are difficult to gather through institutional monographs, built on macro data and on the interviews of a few personalities (among which necessarily many officials). They should be checked and enriched with the direct producers of science[134].

The value of bibliometric analyses

Finally, we also propose that such studies incorporate a significant bibliometric component. Bibliometrics – the quantitative study of scientific publications – is a well-established field of science and involve sophisticated forms of productivity analyses, citation and co-citation analyses, network studies and many more.

Bibliometrics is useful as a tool for comparison as it provide some indication of the comparable achievements and the specialisation of science in different countries, and in a specific country over time. It can also give an indirect idea of the quality and visibility of science ("impact"), and of the number of active scientists (which may be very different from the theoretical potential).

[134] The template for such a questionnaire is available from Dr Waast

For our purposes, a major interest would be in the development of micro bibliometric indicators, i.e. the detailed encoding of establishments within a country and discriminating specialties. It then offers to managers and persons in charge (at the national or institutional level) a very precise view of the capacities, strengths and weaknesses, niches that can be developed, and a knowledge of the main authors ("living treasures" in the country). It even discloses the main teams and networks, the long lasting cooperations, the topics and the ambitions of their programmes. These are strategic tools.

One of the major challenges to conduct bibliometric studies for and in developing countries is of course the availability of appropriate databases. International citation indexes, such as the ISI/Thompson Web of Science, are useful for between country comparisons and other high level studies. Given that most of the developing countries produce very few papers in such indexes, it is essential that efforts be undertaken and supported to help build national databases on knowledge production in developing countries. There are isolated examples of such initiatives, but they need to be accelerated and expanded[135].

The necessity of field visits

Nevertheless the "methodologies" described thus far do not really provide an appropriate entry point into the contents of science or of its prospects. Indicator studies, bibliometric analyses and the use of surveys need to be augmented with on site field visits. Such field visits to selected laboratories (and potential clients) and other scientific establishments by foreign scientific experts of different disciplines, who are aware of the international advances in science (fundamental + R&D) and what is at stake through the world add a crucial element to a country study. In fact, this is a very appropriate method for "small" scientific countries (the operation will not be too long or expensive). It proved to be an excellent source of inspiration for topics to be developed and accompanying measures, in the case of Morocco (this was an initiative of the European Commission: see Book, op. cit.). It helped establishing a diagnosis of the status of science, in a spirit of consensus, and publicizing the quality of science through the whole country.

4.3.2 Organizational considerations

The methodological proposals outlined in the previous section (extended indicators, bibliometric studies, monographic surveys and field visits) would be of little value or long-term value without some effort to make them sustainable and well publicized. There seems to be a simple solution for that: help establishing regional "Centres of Reference", which are meant to become regional "Observatories of science". This could be the first thrust of a new Project, together with some pilot monographs.

[135] CREST at Stellenbosch has in fact developed such a database on South African science since 1998 which allows it to conduct much more detailed field and institutional bibliometric analyses.

Such an observatory (RECYT) already exists in Latin America. Because of that, the data in our monographs are much more complete and credible for that region than for any other. The idea of such observatories (at national level) is now progressing in Algeria, Morocco, Tunisia (where it has just been launched), Lebanon and probably Jordan. There are also similar plans underway in South Africa. Of course, a regional coordination could be the next good step. India and China have their own Centres for that. But a specific effort would have to be done elsewhere in Asia.

Observatories need to have national correspondents. The first step could be to help such "Reference centres" to take off. They would be concerned with gathering data on a regular basis, keeping a repository of surveys, articles and analyses relevant to the topic (often grey literature, soon out of print and lost). Later, the Observatories (through negotiation and an agreement with them) could be put in charge of co-ordination, training, checking the consistency of data, and creating now and then more thorough surveys or assessments.

Up to date, reliable and relevant information is perhaps the key prerequisite for the production of studies to characterise the status of science in the developing world and develop appropriate strategies. Except for the regular gathering of a few significant indicators, the main recommendation is to maintain an information system at national and soon at regional level. Our proposal is that such Reference Centres or Regional Observatories should not only confine themselves with the gathering and analysis of quantitative data and statistical indicators, but also with descriptors (that could be standardized) and relevant narratives.

A process to launch and popularize such an initiative could commence with a few pilot country studies. The condition would be that the relevant governments be interested and cooperative. This first step may consist of an institutional (and chronological) monograph (using the Template outlined here) enriched with a (micro- bibliometric analysis and (as far as possible) a survey of the key laboratories and scientific establishments. These are tools for managing science (at national, and possibly at the level of large establishments). A better (or further) solution would be a full assessment, adding to the monograph on-site visits by international experts. This is a tool for orienting science, toward anticipating niches.

It must be stressed that the basic methodology for such operations has been developed, and put into practice with success in several countries. To some extent, it is now standardized, and a job for professionals. The result is not only helping build timely strategies, but mobilizing scientists and making them better recognized.

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ANNEXURE 1 : African Establishments exceeding on average 15 publications per year

(1991-1999). Source Narvaez/SCI. *Key: 50 %* = contributes to the first 50 % of the national production.

Etablissement	Score	Pays	50 %	Etablissement	Score	Pays	50 %
Universités				**Universités** (suite)			
Cape Town	5144	ZAF	*	Sousse	154	TUN	
Witwatersrand	4500	ZAF	*	Constantine	152	DZA	
Pretoria	2538	ZAF	*	Port Harcourt	150	NGA	
Cairo	2397	EGY	*	USN	146	EGY	
Natal	2311	ZAF	*	Sfax	145	TUN	
Stellenbosch	2145	ZAF	*	Kenitra	145	MAR	
Ain Shams	1616	EGY	*	Sokoine (Agric)	134	TZA	*
Alexandria	1466	EGY	*	Kenyatta	117	KEN	
Nairobi	1355	KEN	*	Annaba	113	DZA	
Assiut	1288	EGY	*				
Orange Free St	1188	ZAF		**Centres nationaux**			
Mansoura	1138	EGY					
Tunis	1088	TUN	*	Nat Res. Centre	1274	EGY	*
Ibadan	995	NGA	*	Med Res Counci	940	ZAF	
Zimbabwe	829	ZWE	*	G. Schuur Hosp	874	ZAF	
Rhodes	650	ZAF		Atomic En Auth	651	EGY	
Rand Afrikaans	647	ZAF		CSIR	477	ZAF	
Al Ahzar (Girls)	621	EGY		S Af Ins Med R.	465	ZAF	
Tanta	576	EGY		Tygerberg Hosp	456	ZAF	
Khartoum	554	SDN	*	Baragw Hosp	291	ZAF	
Zagazig	535	EGY		Nat Accelerator	286	ZAF	
O. Awalowo	533	NGA	*	S Af Astron Obs	281	ZAF	
Yaounde	492	CMR	*	IAV Hassan 2	248	MAR	*
Marrakech	477	MAR	*	Onderstep Vet I	246	ZAF	
A. Bello	473	NGA	*	Hop Ch Nicolle	222	TUN	
Alger	471	DZA	*	Red Cross Hosp	206	ZAF	
Potchefstroom	462	ZAF		Joburg Hosp	194	ZAF	
Casablanca	460	MAR	*	KARI	186	KEN	
Addis Ababa	445	ETH	*	Nat Museums	177	KEN	
Menia	444	EGY		Rabat IIInstInstituts	172	MAR	*
Rabat	443	MAR	*	KETRI	152	KEN	
Nigeria	442	NGA	*	Sea Fish Res I	148	ZAF	
Menoufia	407	EGY		INRST	145	TUN	
Port Elizabeth	382	ZAF		S Af Museum	137	ZAF	

Muhimbili	352	TZA	*	Petrol. Res Inst	124	EGY	
Assiut	334	EGY		T. Bilharz R. I.	123	EGY	
Med South Af	330	ZAF		MINTEK	120	ZAF	
Durban Westvil	309	ZAF		ENS	113	MAR	
Benin	308	NGA	*	Inst Nat Neuro	111	TUN	
Ch.Anta Diop	305	SEN	*	Nat Bot Inst	106	ZAF	
Suez Canal	281	EGY		JLB Smith I icht	104	ZAF	
Ghana	278	GHA	*	Transvaal Mus	103	ZAF	
UNISA	277	ZAF		Nat Ins Med Res	99	TZA	
Monastir	267	TUN		Projet retroCI	60	CIV	*
Dar Es Salaam	266	TZA	*	Trypano	23	CIV	*
Oran	251	DZA	*				
Jos	238	NGA					
Lagos	232	NGA					
Calabar	214	NGA		**Organismes internationaux**			
Western Cape	209	ZAF					
Ilorin	207	NGA					
Abidjan	190	CIV	*	ILCRA	417	INT	*
UST	186	GHA	*	ORSTOM	394	INT	***
Fès	177	MAR		Inst. Pasteur	388	INT	***
Benha	176	EGY		ILRAD	375	INT	*
Maiduguri	169	NGA		ICIPE	283	INT	*
Helwan	164	EGY		IITA	252	INT	*

Annexure 2: Tables of indicators

Basic demographic indicators

Total Pop millions 2003 (WDI 2005)

HDI rank (UNHDR 2006)

PPP gross national income/ Per capita $/ 2003(WdI 2005)

PPP gross national income/ Per capita / Rank 2003(WDI 2005)

Standard S&T indicators

GERD/% GDP

Head-count of researchers

Nr of researchers per million of pop

ISI- papers (2002 – 2004)

ISI Rank

Average ISI papers per 100 000 pop (2002 -4)

SCI pubs per 100 000 of pop

Whereas all our discussions in the other reports have taken region as the determining factor, we have here decided to group our 52 countries into three categories according to population size. The three groupings are arbitrary and merely aims to create more homogeneous clusters of countries in order to facilitate comparison across other indicators. The assumption behind this categorisation is that "size matters" and that one will be able to discern interesting similarities and differences between countries on key S&T indicators more easily when comparing countries of similar size populations. All information provided in these tables is based on the individual country reports included in the regional compilations.

Small countries (less than 10 million population)

Country	Total Pop millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national income/ Per capita $/ 2003(WdI 2005)	PPP gross national income/ Per capita / Rank 2003(WDI 2005)	GERD/% GDP	Head-count of researchers	Nr of researchers per million of pop	ISI-papers (2002 – 2004)	ISI Rank	Average ISI papers per 100 000 pop (2002 - 4)	SCI pubs per 100 000 of pop
Trinidad and Tobago	1.3	57	10390	74	0.12%	518	399	281	103	7.2	8.79
Botswana	1.7	131	8370	83	0.4%	2165	1270	329	97	6.5	6.89
Kuwait	2.4	33	19480	43	0.2%	169	69	1224	64	17.0	20.61
Qatar	1.0				0.6%			77 (2005)			7.7
Oman	2.5				0,05	1200		169 (2005)			6.8
United Arab Emirates	4.0		49 700		0,1	3500		410 (2005)			10.3
Panama	3	58	6420	96	0.36%	1795	600	389	92	4.3	6.51
Costa Rica	4	48	9140	79	0.39	1171	368	622	83	5.2	6.27
Jordan	5.3	86	4290	129	0.67%		1927	1371	62	8.6	13.67
Bolivia	8.8	115	2490	151	0.26%	1250	380	289	101	1.1	1.4
Tunisia	9.9	87	6850	92	0.73%	20050	1013	2275	53	7.7	8.9

Medium-sized countries (population between 10 and 50 million)

Country	Total Population millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national incomea/ Per capita $/ 2003(WdI 2005)	PPP gross national incomea/ Per capita / Rank 2003(WDI 2005)	GERD as % GDP	Head-count of researchers	Nr of researchers per million of pop	ISI- papers (2002 – 2004)	ISI Rank	Average ISI papers / 100 000 pop (2002 -4)	SCI pubs per 100 000 of pop
Cuba	11.3	50	2		0.65%	6027	533	1664	59	4.9	6.02
Burkina Faso	12.1	174	1170	183	0.17%	1319	109	290	100	0.8	0.99
Ecuador	13	83	3440	137	0.07%	845	65	404	91	1.0	1.3
Chile	15.8	38	9810	77	0.61%	8658	548	7006	40	14.8	16.61
Cameroon	16.1	144	1990	161	n/a			727	77	1.5	1.7
Cote d'Ivoire	17.6	164	1400	180	0.90%	1840	104	352	95	0.7	1.65
Sri Lanka	19.2	93	3740	136	0.19%	7807	407	643	82	1.1	1.45
Ghana	20.7	136	2190	155	n/a	1840	89	477	89	0.8	0.69
Nepal	24.7	138	1420	179	0.14%	3000	121	385	93	0.5	0.56
Malaysia	24.8	61	8970	81	0.69%	17790	717	3155	48	4.2	4.82
Uganda	25.3	145	1430	178	0.81%	568	24	558	86	0.7	0.78
Venezuela	25.7	72	4750	125	0.28%	6100	236	2819	50	3.7	4.34
Peru	27.1	82	5080	117	0.10%	4965	183	793	75	1.0	1.17
Morocco	30.1	123	3940	132	0.79%	18000	598	2600	52	2.9	3.45
Kenya	31.9	152	1030	189	n/a	2400	35	1588	61	1.7	1.84
Algeria	32	102	5930	103	0.70%	4408		1615	60	1.7	1.84
Sudan	33.5	141	1760	167	0.34%	9340	263	250	104	0.2	0.28
Tanzania	35.9	162	620	206	0.35%			663	78	0.6	0.72
Argentina	36.8	36	11410	66	0.39%	43609	720	13358	32	12.1	10.91
Colombia	44.6	70		97	n/a	10851	109	2088	55	1.6	1.64

Large countries (population larger than 50 million)

Country	Total Population millions 2003 (WDI 2005)	HDI rank (UNHDR 2006)	PPP gross national income/ Per capita $/ 2003(WdI 2005)	PPP gross national income/ Per capita / Rank 2003(WDI 2005)	GERD as % GDP	Head-count of researchers	Nr of researchers per million of pop	ISI-papers (2002 – 2004)	ISI Rank	Average ISI papers per 100 000 pop (2002 -4)	SCI pubs per 100 000 of pop
Philippines	81.5	84	4640	128	0.1%	8692	107	1107	68	0.5	0.59
Bangladesh	138.1	137	1870	163	0.03%		46	1118	67	0.3	0.35
Ethiopia	68.6	170		201	n/a	4070	59	595	84	0.3	0.09
Mexico	102.3	53	8980	80	0.40%	33558	268	16679	27	5.4	7.63
Thailand	62	74	7450	87	0.26%	29850	286	5366	43	2.9	3.18
Indonesia	214.7	108	3210	142	0.05%		438	1284	63	0.2	0.22