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Mapping research systems in developing countries

Country review template

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THE COUNTRY REVIEW TEMPLATE

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Introduction

This document presents a new tool for mapping research systems in developing countries. The tool – referred to as a "template" for studying research systems – is the result of a comprehensive review of research systems in 52 developing countries conducted over the past two years. These countries were selected because they have – for the most – not been studied in any great detail and are sometimes regarded as being of secondary scientific importance in the global scientific arena. The individual country studies as well as aggregated regional reports and a synthesis report are available elsewhere (website).

Another part of our Brief was to develop a Template aiming at collecting and organising the minimum of data needed by policy makers, science managers, advisors and other stakeholders in order to facilitate their task. In our view such a document would have to be structured in such a manner that it is easy to use, sensitive to different contexts (countries, sectors, levels of responsibility…), and sufficiently complete to encompass pieces of information desirable in certain situations, or fortunately accessible in some cases (though not essential, and not always available).

Templates are, according to our understanding, heuristic devices: they guide and direct; they are indicative rather than stipulative. This template is no different. It is a tool that we propose for studying research systems, especially in developing countries. Like all tools it has its strengths and limitations we wish to point to one possible limitation.

Our country and regional studies, referred to above, mainly focus on the **structure** of research systems. As a first exercise of its kind, our focus was on the pitfalls of data collection for policy making in the developing world. Evidence of the assets and lie of the scientific land is required *before* taking timely initiatives. There is a need for *a panorama* (instead of the distinctive, but necessarily limited experience of any stakeholder or executive). This is all the more difficult given that the relevant information is scattered (across different establishments, departments, sectors), sometimes withheld by its keepers (who may be unaware of it); and it is very quickly lost (for most of it appears in reports or grey literature, with few copies and little attention). One of the main weaknesses in these countries is the lack of a local office or institution in charge of collecting and archiving such data, reports and relevant articles.

Another difficulty is that indicators (which are typically used to describe the state of the research system in developed countries) may not be attainable in developing ones; or they may be of little relevance.[1] In any case, information of other kinds is necessary to describe the specific structure of science in these countries. Unfortunately, there is no standardized list of such information. We tried to fill this gap by developing and articulating a Template. We do not claim it to be valid irrespective of use or context.

Because of the points made above, we believe that the main shortcoming of the Template is that it may lead to a neglect of **the dynamics in the research systems**. We have, as far as possible, attempted to address this challenge through the inclusion of appropriate sub-headings and descriptors. But as we already stated, our concern was first to help in *grasping the structure* of the system. The addition of a tenth category (labelled "Dynamics") to the first version of the template is another attempt to address this concern.

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. As argued above, 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 TEN 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.

Finally, it is also important to understand that the Template is organized around THREE "dimensions" that each captures a different **purpose** when reviewing research systems: the **context** within which the research system operates; the **components** that constitute the system and the **dynamics** of the system.

[1] E.g. the number of patents registered – for innovation goes through other paths.

Four categories are included under context: General country context; History of science in the country; Governance of science in the country and Informal S&T structures. The next FIVE categories refer to the components of the S&T system: the Performers (universities, “schools” for engineers, research centres – public, private and international); the Human resources; the Funding; the Cooperation agreements (formal or not); and finally: the Output. And as discussed above, we have added a tenth category to capture the dynamics of research systems. This category is entitled “Tensions, dynamics and challenges” and includes reference to grasp (principally through narratives): the social inscription of science; the values and the ethos of science; the legitimacy, credibility, accountability of science; the link with the state; the link with different parts of the society; science and its publics: popularization, controversies around science; and the debates about the “usefulness” of science (and how this question is put locally).

THE TEMPLATE

Purpose	Category	Description	Nature of data
Context (1)	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
Context (2)	2. 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
Context (3)	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)

Template continued

Purpose	Category	Description	Nature of data
Context (4)	4. 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
Input / Output (1)	5. 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

Template continued

Purpose	Category	Description	Nature of data
Input / Output (2)	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 Master's 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

Template continued

Purpose	Category	Description	Nature of data
Input / Output (3)	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
Input / Output (4)	8. 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	

Template continued

Purpose	Category	Description	Nature of data
Input/ Output (5)	9. Research Output (post-graduates/ publications/ papers/ patents)	Total output in ISI-journals (by scientific field) Total output in local journals (by field) Nr of Master's 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
Dynamics (1)	10. Tensions, dynamics and challenges	Social inscription of science The ethos's of science (values) Science and the state/ contract Legitimacy/ credibility/trust/ accountability Science and its publics Usefulness of science?	Narrative

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

[2] 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.

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 1985-2004	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 enrolment 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

1 - Estimate based on regression.

Sources: World Bank. World development indicators 2005

The unemployment data are from the ILO database *Key Indicators of the Labour Market*, third edition.

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	

National science continued

Year founded	Name	Fields	Status	Administrative supervision	Notes
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	

National science continued

Year founded	Name	Fields	Status	Administrative supervision	Notes
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:

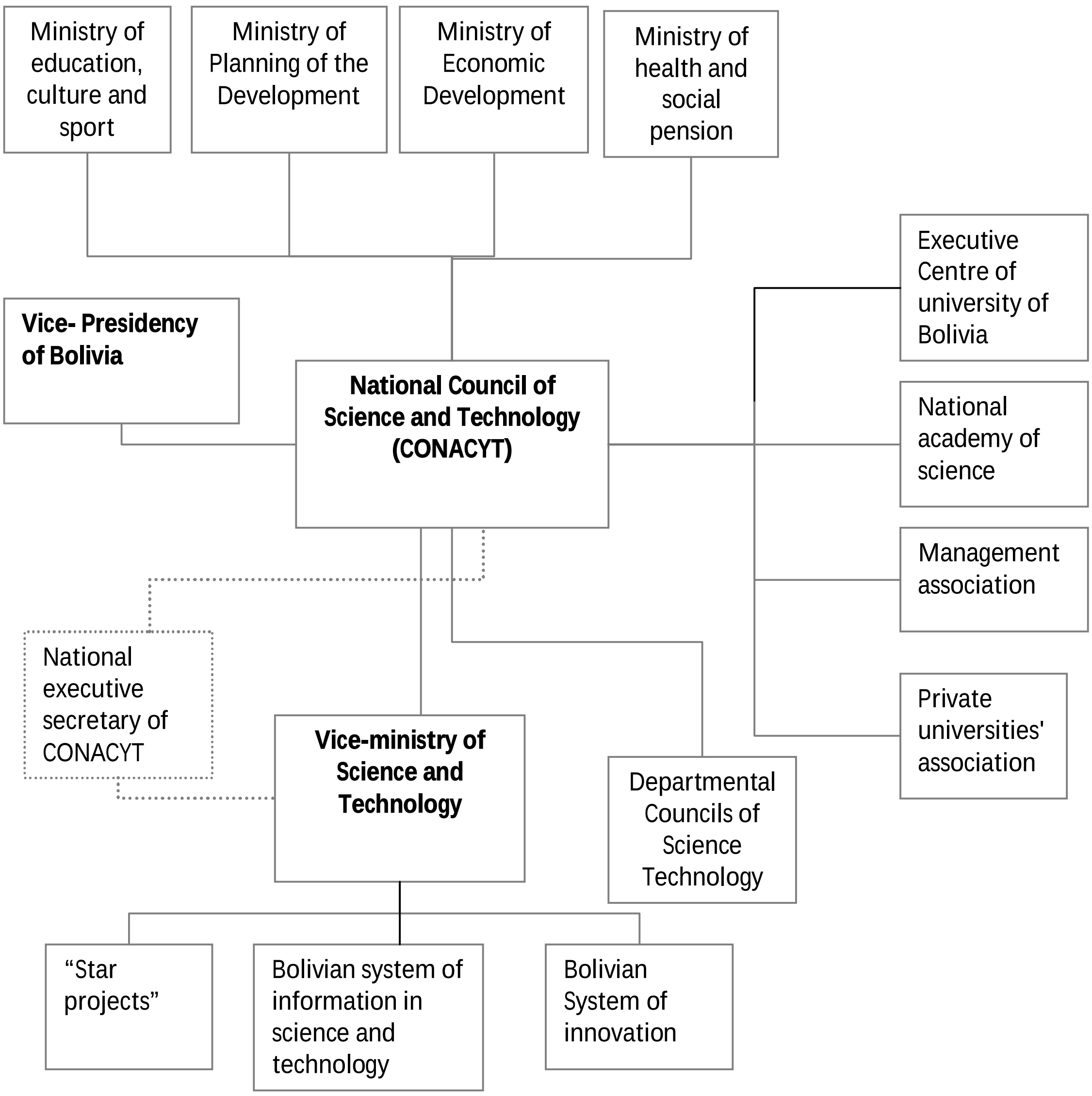
- The use of research to resolve the country's principal socio-economic problems (health, nutrition, education and housing)
- The funding of programs that help the formation of the National Science, Technology and Innovation System (SNCTI – acronym in Spanish) in the following areas: basic science and 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: Informal S&T structures

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

EXAMPLE 7: 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 8: CAMEROON

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 Cameroon

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[3]

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

Ecole Normale Supérieure

Journal : *le Savoir*

[3] 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.

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

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 5: Knowledge and R&D performers

(Establishments/ Institutions/ Universities/NGO's)

EXAMPLE 9: ALGERIA

Descriptors

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

Descriptors continued

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

Descriptors continued

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 dependant on 16 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 10: 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 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 Master's 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 stayed 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

Evolution of external funding continued

Years	1987	1988	1989	1990	1991	1992	1993	Total
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
Belgium	20							20
TOTAL	7,465.9	2	1,5	433	5,061.6	653	2,14	17,755.6

Section 8: 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 15: 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 16: 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:

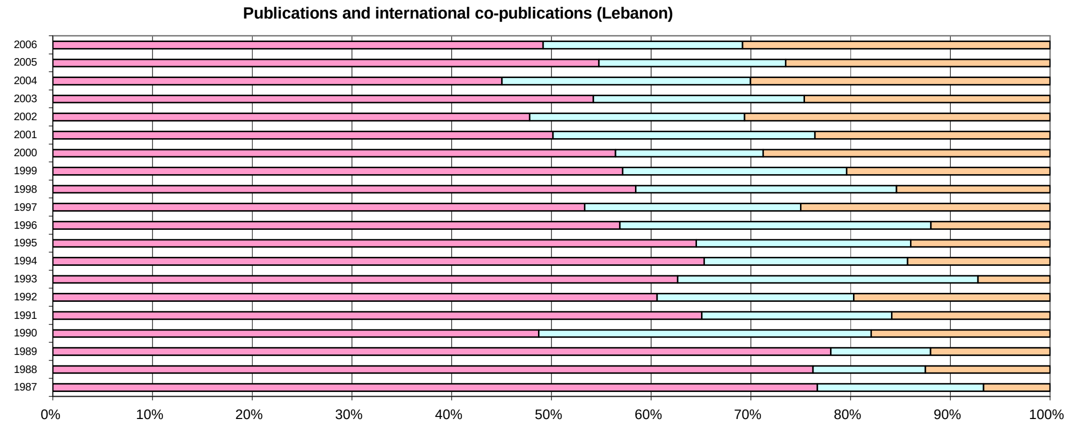
- The Tropical Agriculture Centre for Research and Training (CATIE – Spanish acronym),
- The International Centre for Tropical Agriculture (CIAT – Spanish acronym),
- The Inter-American Institute for Agricultural Cooperation (IICA – Spanish acronym),
- The Biotechnology Sub-Program of the Latin American 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 17: 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 18: 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.

Section 9: Research Output (post-graduates/ publications/ papers/ patents)

EXAMPLE 19: SRI LANKA

Indicators and narrative

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

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 PhDs, 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
University Peradeniya	142	Inst. of Fundamental Studies	77
University	82	Industrial Technology	9
Colombo		Institute	
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 20: 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[4] 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 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.

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

Section 10: Tensions, dynamics and challenges

Up to now we have tried to describe the components of the research system and their arrangements and configurations. One might have gained the impression thus far that such a layout works smoothly and harmoniously. Fortunately, this is not the case - there is potential for advancement and changes. This comes from the tensions within the system and the challenges it faces from outside. They have to be grasped, in order to make them productive.

(A) What are we referring to?

Tensions may exist within the system (its actors) between

- different sectors (several Departments supervising research establishments; firms' demand and public offer),
- types of performers (universities and "Schools" for engineers, private and public centres),
- types of researchers (academic and engineer minded researchers),
- corporate bodies, etc.

Challenges are unexpected and often external events, out of control. Examples are:

- the arrival of multinational firms with their R&D centres, challenging the national research centres that were the main source for new technology in the country (India, Brazil, etc)
- the advancement of world science and technological paths; the change in high technological stakes
- head hunting of talents hired or taken away by foreign agencies
- and of course some typical features of the context, like geographical segmentation, diversity of the identities and languages, or change in the economic strategy and resources

"*Issues*" are the rephrasing of tensions and challenges in terms of problems to be solved. Examples are:

- Brain drain and the Diaspora option
- Incentives for researchers?
- How to induce a collective mind in an establishment?
- Which appropriate proportion of basic research to support?
- How to choose relevant topics and to which niches of research give top priority?

Initiatives are the schemes of action developed by a diversity of actors. These may be governments (e.g. the government of Malaysia developing a policy of "clusters" where firms and research universities or centres are brought together in specialized niches); or Agencies and Foundations (as those facilitating the setting up of foreign campuses and firms in some Gulf countries); or executives in charge of the management of establishments (as presidents of universities); or even persons in the general public (as leaders of controversies around scientific endeavours like genetic engineering or large dams). The range of actors and initiatives is very large. The important thing will be to select the most significant ones, able to have an impact on the advancement of science (in the establishment / country / region) or/and to be considered as a "good practice" or a general model.

(B) What are the main areas to be investigated?

We may classify the main areas to be investigated as follows:

- The context and its *constraints*: Assets and obstacles, among which the History, the development strategies (past and present), Trust in science in the general public (or in particular communities), the Social environment and Support to science…
- *Human* resources, looking at numbers (critical masses), Quality (training and epistemes), Profession (remuneration, careers, regulation), Values and modes of knowledge production, Brain drain and the Diaspora resources…
- *Institutions*: their diversity (universities and research centres, different sorts of universities), their competition, their roles (sanctuaries for basic research, sources of technology, adornments); the present tendency to a de institutionalization; managerial issues and cooperation challenges…
- The *output*: different sorts; strengths and weaknesses; measure and assessment; controversies around usefulness; excellence and relevance; choice of apropos niches and topics; liaison with firms and society; adequacy to the world advancement of science and technology…
- The *function* of research: Understanding of science and its powers; Vision and adequacy to the future; Expectations, Credits and capabilities; Anticipating niches and innovation.

The following section contains a detailed discussion of these issues.

(C) The context: Assets and Obstacles.

This is an important section. It encompasses some of the main sources of tensions, predispositions, motives and triggers that constrain or encourage the potential advancement of science. Though this is NOT an exhaustive list, attention should be paid to the following headings (but it is worth noting that a good user may add specific sections, according to the particulars of his/her action field or living context: e.g. health, agriculture, cooperation…; and fragmented geography, multiculturalism, etc.)

1) History plays its role. The type and length of colonization[5], the time elapsed since then (enough to develop locally a "space for science" [Schwartzman]), the seniority of establishments dedicated to knowledge creation are powerful determiners of unequal endowment and moods toward scientific activities. Latin America is a good example: colonization there is an old story; there has been ample time to establish everywhere numerous universities; though successive governments were sometimes "abusive" in their treatment of scientists, a profession has been built and institutions are thriving. Science indicators are clearly better than in any other region. Other examples are South Africa, Egypt or Thailand – which have a long story of autonomous science and which were only

5 Though it bequeathed some knowledge and institutional models – like research regional centres staffed with full time researchers in specialized areas: agriculture and health -. But it rarely developed local capabilities and encouragement to research.

“semi colonies”. But there is no mechanical link. Late independent countries may also take initiatives, as Cuba (and Maghreb) did energetically by the end of the seventies.

India is a special case: in spite of the barriers set up by colonial science some Indians achieved brilliant intellectual work and eventually won the Nobel Prize. Supported by the nationalist movement they became the coat of arms of science in their country (Rahman is the best known example).

It must be stressed, by the way, that sometimes the historical role lies less in “whole countries” than in specific establishments, which are “sanctuaries” for research where and when there is no continuing interest in it. Examples can be the Saint Joseph’s or the American University in Beirut. In most places there is a specific role of a few establishments; and often the oldest are the most attached to high standards.

Renowned scientists too may have a lasting influence, as Nobel prizes (Rahman, Abdussalam) or other talents who were the pride of their country and set up deep seated Institutes (like the Institute of Physiology of Bernardo Houssay in Argentina, or the Oswaldo Cruz Institute in Brazil).

History is instrumental to disclose the main tensions in the system (fragmentation, various epistemes) their roots and their consequences (support to research, understandings of science). It helps to clarify the issues resulting from them. It is commendable that studies be commissioned to true historians, preferably historians of science.

2) Development strategies, past and present, have powerful and enduring effects. Singapore is a good example. For half a century this country has been driven by an export economy and interventionist government. Beginning with the disciplining of workers and modest technical ambitions, they rose to the training of professionals and the production of more technological goods, up to (by now) the growth of a powerful scientific community, training high capabilities and devoted to strategic or applied research in computer science and biotechnologies. Publications grew in the last 20 years from a low 500 to more than 5200 in 2006, a score of emerging country: which shows, if necessary, that the size of the country is not the decisive factor in scientific production.

Conversely, countries relying on income from natural resources (for instance the oil economies), or striving towards the pure development of services (as most of the Caribbean countries) do not really need science and research. They may maintain universities, invite there top flight teachers and support the research they pursue for their own career and the prestige of sponsors (as in some Gulf countries up to recent days), but their commitment is unsure (as could be seen in Nigeria, the Democratic Republic of Congo and a number of other places).

There is a clear link between the development of science and industrialization. The nationalist governments that tried to develop import substitution, even when they failed in that plan, generally established a science base which remains a national asset for the country (see Brazil, Egypt, Maghreb countries and a number of others).

3) Trust in science. There must be some pact (at least implicit) between science and the society. For long (since WW II), the opinion was that the development of science benefited the people and induced naturally new salutary technologies. It was the source of progress for mankind; its support was the duty of the state and results should be public goods. This applied to the developing world as well as to the developed one and lead to the building and growth of national research systems.

But since the mid 80s events have been influences by a new trend. Well-being was no longer sought from the state but from enterprises, and progress not from science but from the market. The "national" mode of knowledge production fell into disgrace. More linkages had to be established with the economy. This mood more often than not led to a withdrawal of state support, and sometimes to the disparaging of local scientists as "pure" parasites (Tanzania, Nigeria, Bangladesh).

Of course, even during times of misfortune, science may have a pact with parts of the society (distinctive communities, aristocracy, nationalist military in power…). This was the case in Asia, in Egypt, in Latin America on several occasions (Venezuela, Argentina, Brazil, during the beginnings or under dictatorships) and in South Africa during apartheid. Nevertheless, it seems better that there is some general consensus (or debate) about the uses of science. Its best grounding seems nowadays to be in the pursuit of *innovation.* It implies energetic support from the state for "strategic" and applied research, organized in "clusters" in collaboration with dynamic firms.

Today the case of "*intermediary countries*" (most of those present in our Meta Review) is of special interest. Time has come for bold initiatives. Emerging countries (South Korea, India, China, Brazil) have already chosen to gamble on innovation. They develop at forced march their industry, and a booming science base[6]. Some intermediary countries are decidedly taking the same path. Malaysia and Thailand, Chile and Argentina, Mexico and Costa Rica, Qatar and Tunisia are some of the examples. They create new productive sectors (in carefully chosen niches), modernize the existing ones and devise imaginative schemes to bridge the gaps between research and firms. This shows that there is room for daring initiatives[7]. This is not a question of the size of the country (or even of its wealth, for there may be joint ventures with external funding); but of the constant pursuit of a path, and of trust in science and technological development.

On the contrary, a number of intermediate countries hesitate to embark on this discriminating strategy. They have scattered initiatives that occasionally fall within it, but no sustained and coordinated policy. From a science standpoint (and probably from a development one too) this may quickly make a difference. As a sign of it, the growth of publications in Tunisia is much more spectacular and sustained than in Algeria and Morocco (which had to and fro in their support to research during the last two decades). The same is true when comparing Andean or Caribbean countries with those of the southern cone in Latin America.

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6 The growth of their publications is spectacular. See our *General Synthesis*.

7 Singapore oriented its science and technology in opportunity niches: computers first, then health biotechnologies. Qatar is facilitating the settling of foreign campuses and firms. Costa Rica began with a spectacular joint venture with multinational pharmaceutics around medicinal plants. Tunisia is supporting research without flinching and gambling on the future of an ICT industry. Mexico promotes schemes to develop research in remote provinces. Malaysia launches "clusters" gathering firms and research for specific branches. And Chile (as well as South Africa) is multiplying schemes to encourage research in (and for) all types of firms. See our *Meta Review*.

d) *Social environment* of science is an important component of the motivation of scientists. Trust from its employer (often the government) is part of it. But social values all around are another dimension. Some nations have traditionally held science in high regard - India, Egypt, Viet Nam and Thailand. Others have not had such traditions (or they have had other understandings of what valuable knowledge is). Values of political power or material wealth may supersede all others in imparting a certain kind of status on science. Religious values, values related to aristocratic ancestry or to the family may predominate and override all other considerations. These features may well interfere with the commitment to science and its demands. Among others, some Arab countries are a well documented case where self censorship for religious or political reasons play their part, and where the family duties supersede professional obligations. In a number of places, this may reach the point where practising research has no other meaning than fulfilling the formal requirements of building one's career.

This is why a number of scientists in the developing world aim to work in research centres, where (so they think) they will escape a too heavy burden of teaching, and too many extra professional demands. At least, this situation calls for a debate on the interest of promoting local (or regional) "*Centres of excellence*", dedicated to science with sustainable support, high standards and relevant focus.

Another conclusion is that there is a constant need for scientists to *develop role models*, and promote the understanding of science. *Popularization* of science is part of the scientists' trade. And there should be appreciation within scientific communities for different kinds and levels of research: pure and theoretical of course, but applied science too, and even development and action research. There are interesting examples of the peaceful coexistence of several circles and arenas for example in biology in Egypt, where a few teams have impressive international credits, while many others just develop very simple devices (which they even go and sell to peasants in the neighbourhood) to protect local plants from characteristic insects. In India as well the participation of engineers and scientists in movements and research centres that develop and diffuse incremental improvements of tools for poor peasants is a well known and regarded activity. The same is true in many places, especially where research is not well established: see the action research at the West Indies University in the Caribbean, or in Mozambique (about agriculture).

Of course, such achievements are not properly reflected in the international bibliographic databases. But they are very useful to the entire society. The lesson is that in the developing world, popularization is part of the science system; and it requires support and efforts from the scientists themselves, more than elsewhere.

(D) Human Resources.

After investigating the constraints in the system, we now look at the other end of scientific production: beginning with the individuals involved, the (more or less) talented persons in charge of generating knowledge. Though many issues relate to this chapter, we shall concentrate on a few of them; namely: questions of numbers and critical masses; quality; the profession (including evaluation); and its reproduction (including brain drain and the "circulation of minds").

1) Critical mass. The output is roughly indexed on the volume of staff. The number of researchers (headcount) is broadly known. But: which part of them is really active in research? Official figures are very deceptive (number of researchers FTE). Local studies and assessments are useful (if available).

The bibliometric approach has proved to be appropriate for “intermediate countries”. The main result is that generally the bulk of the scientific production in one country comes from 2 or 3 establishments. Even in these establishments, only 10 % of the possible fields of science are significantly investigated. And in each of these fields, the production rests with a handful of very active scientists (5 to 10), backed by a score (or less) of active and fleeting others [ESTIME]. There follow the questions of a *critical mass* in specific areas; of the reproduction of capabilities, of the updating and renewal of subjects and methods. A full range of management questions is open: how to develop relevant international co operations; how to build appropriate networks; how to consolidate efficient niches. Especially in intermediate countries (and marginal establishments) research remains fragile and needs incentives.

*2) Quality of the researchers .*There are two aspects of this question. The trivial one regards the training (and *re-training*) of the researchers. The least-known one concerns their Episteme. The qualification of researchers by training is very unequal between countries (and often within a country: between Universities and Centres, between Universities themselves…). In all cases, they have to refresh their knowledge. This generally happens through intensive reading, travels, participation in international programmes and congresses; it may even require further training (which may be part of cooperation agreements: see numerous US-AID schemes). Arrangements for all such conveniences are important concerns for the science managers (though unfortunately less understood and funded than appropriate equipment): sabbaticals, missions abroad, transport facilities and easy access to internet, access to a huge and up to date documentation (which may often only go through a national subscription to electronic scientific journals). Others may be added: incentives to publish support to journals, etc.

The second dimension of quality lies in “***Episteme***”. By this we refer to the scope of problems which the researcher considers worth addressing and likely to be solved through “scientific” investigation. This is often a matter of style of thinking (deductive, inductive, retroductive, etc.). This might also have to do with education, the type of establishment where the scientist was trained (for instance universities versus engineering schools), the science curriculum (with more or less experimental practice), job conditions and expectations and the research culture (or lack thereof) of the establishment where he/she is employed. This might mean that the scientist is more open to theoretical or applied approaches, and considers problems at specific levels (full complexity limited at local level, or simplified approach at global level…). Such a posture makes a difference between several populations of scientists, who have fields of success of their own. It has long-range influence on the choice of topics, the ability to liaise with firms and society, and it opens out onto numerous tensions (expressed in terms of “excellence” versus “relevance”) that have to be made productive; as well as on difficult questions of evaluation (different sorts of output).

3) Profession. The motivation to and orientation of research are dependent on the working and living conditions of the researchers. Though action parameters are not many (except for national policies) a few comments are in order. During the 1950s-1980s the profession of the researcher in Centres and that of teachers in higher education even more could be seen as rewarding (remuneration, respect, freedom of research and connectivity with the best of the world scientific community). Since then things have changed in a number of countries (impoverishment, drop in status, overload of teaching and mandarin or bureaucratic management). As recruitment was frozen a large part of the profession is now made up of a proletariat of “casual or contract labourers”, with poor career prospects and significant turn over. Things went often so far that it became almost impossible for a researcher to make a living for his or her nuclear family. The result is the well documented brain drain, deskilling of many academics (who acquired a second or third job), changes of trade and for a small number the making of a living through their research capability by being hired, for short contracts, by international organisations or foreign labs.

This is a *new "mode of knowledge production",* far from the previous "national" or academic one with its values and regulations. The hierarchy of disciplines has changed (some are more "marketable" than others), the prioritization of values too (academic credentials are challenged by the amount of contracts won) and the regulation of the profession is less in the hands of the scholarly community than in those of the international laboratories and sponsors. This entails conflicts of epistemes and values, problems of incentives and evaluation, and huge managerial challenges to promote a collective dynamic and pilot the agenda.

Has *consultancy* work become the normal mode of knowledge production? At least in a number of low-income countries, poor living and working conditions force to it many academics (most often for the benefit of foreign agencies). An interesting study has just been completed about the reasons driving it in SADC countries. The main arguments put forward (with much less intensity in South Africa) are as follows:

- Consultancy improves my knowledge and skills: "SADC": 92%)
- Consultancy advances my networks and my career: ("SADC": 72%)
- Inadequate salary (cited by 69 % respondents in "SADC" out of South Africa)
- My research interests are not addressed by my own institution: ("SADC": 47%)

This is a list of issues worth being considered by policy makers and by executives in charge of research establishments.

Brain drain is another serious issue relating to the availability of qualified human resources. *Measures* are not easy to come across: this is a challenge to be answered (longitudinal surveys to be conducted). Yet reliable data show that in the Caribbean and Andean countries, there are larger or equal numbers of nationals working in R&D (FTE) abroad than at home. The same is true for most of Middle East countries, Egypt and Algeria. A recent study showed that 1 researcher out of 4 planned moving to another country in the near future[8]. These are only scattered data that illustrate the size of the question [Diasporas].

Brain drain (internal and external) is often the sign of ill-treatment to the professionals (poor living or inappropriate working conditions). When giving up undue curses toward the runaways, the policy makers may discover different options to thwart the phenomenon. Singapore and China have been clever (when it became a necessity) to identify their qualified citizens abroad and offer them at home positions of directors of laboratories (part time or full time). India passed regulations helping them to set up small firms sometimes combined with academic positions. Softer and stronger variants of the "diaspora option" try to take advantage of the frontier knowledge and networks of their foreign residents grouped in associations (Colombia, Morocco). Another solution is simply to structure properly the Research as such, and recognize its function (Tunisia won great successes in that way): for many researchers just want to carry on a "normal" scientific life, within a friendly environment and an acceptable valuation of the profession.

[8] 1 out of 7 in South Africa.

There are great differences between countries in the way they deal with the researchers. This may be true even in the same region. For instance, in Tunisia and Morocco the profession remained a good and respected trade; while in Algeria and in Egypt researchers have been ill-treated. In Burkina academics were always respected, while they have been despised and ruined in Nigeria (a much wealthier country). Much depends on the regime, the power of academics' trade unions, the support of socio cognitive blocs, the type of economy and the national development strategy. What is clear is that countries now resolutely embarking in an innovation policy always paid (or are now paying) a renewed attention to the profession. A good indicator is the *ratio of a researcher's salary* to the income of liberal professionals, or to that of senior officials' representative of the authority (army, justice).

4) Evaluation. However, the counterpart for the interest of the State is that it generally sets strict evaluation rules for the professionals. For instance, in Latin America a system of "national researchers" spread through the continent, promoting significantly a small number of deserving researchers [Villavicencio]. It has now been completed by a scheme for budgeting groups (and not only individuals), selected after strict screening. This is a new way of funding. The government may also launch calls for tenders, strive to boost research in remote places (Mexico, Chile) and organize the players in teams, within "clusters" where they are supposed to have business intercourse with firms (Malaysia, Tunisia…). In these (favourable) cases, academy and the establishments have much less control over the quality, choice of topics and orientation of research. In other cases (countries which do not trust science; other results than those valued) it is up to the researcher (or team) to find his/her own budget through persuading sponsors and international linkage. Many academics prefer to refrain from such activities.

Whatever their attitude, assessment and evaluation has become part of the "new pact" between science and society. It implies a number of new institutions: undisputed Commissions of specialists (often partly international), assessment bodies and exercises, rules and means to deliver rewards and penalties; and specific tools: like observatories, output databases etc. It implies also that the core funding of establishments is limited, running costs for research are linked to contracts (individual or not) and policy makers have to show incentives and take initiatives to mobilize the human resources and link them with innovation (or other social objectives).

(E) Institutions.

Does contract research (and the circulation of minds) tend toward a *de-institutionalization* of science? In a recent paper D. Wight[9] cautioned: "Most of our social scientists are not institution based - they are there for hire". For sure, as long as (in spite of their rhetoric) governments view research as a luxury, and individual scientists receive their funding directly from foreign sponsors, they tend first to satisfy these sponsors, then focus on their own scientific interests, career and best localization for further achievements. According to some opinions, this may be an appropriate organization for science. The world market is most able to suggest the agenda; and the market of brains guides them toward the best places to exercise their talents. The task of governments is to offer the best conditions to territorialize the best researchers, and each place in the world will thus have what it deserves[10].

9 Wight, D. 2008, Research consultancies and social science capacity for health research in East Africa. *Social Science and Medicine, Vol. 66: 110 – 116*

10 This approach inspired recently radical measures to some Gulf countries (Qatar, Emirates): they have built grand "Science Cities" and offer their facilities to foreign prestigious universities and firms.

Nevertheless, when capacities get over exploited they wear out. Scientific capabilities and technological knowledge are fragile and *perishable goods*. They need to be up dated, reproduced and nurtured in a friendly environment. This is why science systems in developed countries have a number of scientific institutions (not only performers but publishing houses, journals, conferences, workshops and seminars which contribute to a vibrant debate; and technology incubators, technology transfer offices, patenting offices and so on that promote the utilization and commercialization of scientific knowledge). They perform clearly articulated functions and roles and together constitute what could be termed the "national mode of scientific production". The "national mode" means that science is conducted for the public good and that the direction of science is shaped and steered by a nation's socio-economic needs.

There is today a renewed responsibility of the State for that. And there are also *tough challenges for performers.* First of all what is the specific role of Universities? At least a number of them should be the sanctuaries for some basic research, intellectual competition and the ethos of science. They are best placed to link with the global knowledge and its advances. They have the mission to train (and re-train) new academics and sustainable executives as well as qualified staff for the whole society. But they have also to manage a *full spectrum* of researches, from basic to strategic and applied. This may need to change their episteme. It entails numerous management innovations: building a collective dynamics, inventing incentives, identifying relevant niches, canvassing clients. A policy problem is whether to support one (national? regional ?) "research university" or to irrigate a whole network of local establishments (one practical issue is where and how to organize doctoral courses, and which of them are à propos?).

Other challenges confront the Research Centres. They can no longer pretend to be the only source of new technologies for the country. Should they turn to development and demonstration, bringing incremental innovations as a private research could do? Would they concentrate on specific programmes of national interest – especially insolvent social ones? Would they undertake to supply sophisticated services to firms (national or multinational) at home and abroad? New managerial strategies have to be carved. A policy problem is: should there be a support to international Centres of excellence (in which areas: health, agriculture…?) or should national centres be privileged (or at least nurtured and liaised – how? - to regional ones)?

The role of institutions has never been as important as now, to shelter upgrade transmute and reproduce the capabilities at an age of quickly growing advancement of science and technology. Their weakness or waning influence in a number of countries is a serious issue, hampering their progress. There is a responsibility of *cooperation schemes* to turn round this tendency. Ultimately the restoration and improvement of research institutions and specifically many universities in Africa requires *a strategy that focuses on institution-building* interventions rather than on building the capacity of individual scientists. This does not mean that training of and support to individual scientists, whether they are emerging or established scientists, is unimportant. On the contrary, our proposition is that such individual capacity building should be embedded in a framework of building the institutions of science. The aim is to develop (through specific means in each situation) a sustainable scientific life locally. Good examples of such projects are for instance the networks supported by the Swedish ISP; or the French programme supporting mathematics in Africa (Sarima), which help to establish laboratories (supervising doctoral candidates) and insert them immediately in regional networks.

(F) Output

There are tensions and issues around research output which sometimes go unnoticed. We shall elaborate on the quality of the results (and their measure) the relevance of topics and the linkages that the output needs.

1) Quality. It should be remembered that there are several epistemes (conceptions of what worthy science is), differently minded researchers and therefore different sorts of output. According to Burawoy (in sociology) there are four main orientations according to their approach (reflexive or instrumental) and to the public aimed at (academic or not) [11]. In experimental sciences, one could as well differentiate efforts to develop theory, or methods, applied research and development research. In Burawoy's eyes [Burawoy], a discipline is in good health when the tensions between the different types of knowledge are balanced, making the discipline vibrant, controversial and enterprising.

This in turn challenges the evaluation of results. It is easy to measure the number of publications indexed in ad hoc databases. But specific assessment schemes and tools need to be elaborated to approach and treat fairly other achievements[12]. Assessment by international experts proved to be an appropriate method for intermediate countries, provided they are well chosen[13].

Finally, the detailed account of activities is not enough. If the question of quality is raised, one should know something about the *impact*. Some databases allow for measuring the number of citations received from colleagues by each article indexed. This is a good indicator for academic science. For "non academic" works (applied and development research) other descriptors have to be designed, e.g. relating to products and processes that worked and reached the market. There is no standard method, and assessments have to be tailor-made.

Relevance is another issue. The policy question is: which opportune niches are worth being supported? The researcher's and manager's issue is: how to discriminate relevant topics? Contrary to clichés, it is insufficient that they relate to pressing concerns as they are felt and formulated by the people or by the policy makers; or that they deal with present resources or harms of the country. They have to be anticipating (because discovery takes time) and as far as possible to adjoin stakes of world science and technology. The strategy to detect them is a difficult one, especially in intermediary countries (who are not first comers). For example: working on a medicinal plant widespread in the country may be a wrong idea if this same plant is also spread in many countries, most of its characteristics have already been investigated and published abroad, and powerful multinational firms are exploiting patents in relation to it. A better choice is to work on endemic flora or fauna, (which of course is more difficult because there is little previous literature about it). Multiple other examples can be given[14]. Choosing a "good topic" needs erudition, a good knowledge

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[11] The four types of knowledge created are: professional sociology (instrumental academic), critical sociology (reflexive academic), policy sociology (instrumental non academic) and public sociology (reflexive non academic).

[12] Patents are generally not a good indicator of applied activity in intermediary countries. For specific devices, See the "SETI" evaluations of research Councils in South Africa (with panels of clients). Even the evaluation of the publications through the classical databases (like the World of Science) is now much debated, and other – sometimes ad hoc - databases are being tested.

[13] See the Evaluation of the Moroccan research system by international experts (and its methodology) [Kleiche].

[14] In medicine, working about local specific genetic diseases may be a shortcut to innovative knowledge and a mid term advantage for public health. It may be opportune to develop capabilities in new methods (molecular biology…) regarding old problems (seeds breeding) or in new disciplines for new industrial branches (e.g. ICTs).

of the advances of science and world technological stakes, imagination and a sound estimation of what is feasible (with which partnership). The same is true for the national choice of anticipating and profitable niches, which needs informed advice from panels of international experts (engineers and scientists). Singapore is well known for such an approach, and "innovative" countries all practise it in a more or less formal way.

2) Collaborations and linkages. Relevance, as well as making noticeable contributions requires cooperation and international links. These can be mapped through the display of networks which bibliometric analyses may disclose (study of co authorship). This tool is useful for managers and policy makers to monitor current policies and to assess the strength and ambitions of specific laboratories and leading figures (long or short networks, opened or curled up, entailing to which extent national and international collaborations).

What is certain is that taking part in large international programmes is an advantage to catch hold of up-and-coming advancements in science and technology and to detect the most strategic (useful, promising) for the researcher's country. This is true provided the national laboratories are involved in huge programmes through a fair international division of work (not only as subcontractors). In that respect there is a responsibility for the cooperation schemes launched by the developed areas (with certainly some model programmes of the WHO, the USA (new materials), the European Union and other bilateral co-operations).

(G) The Function of Research

Let us conclude with a few words concerning "the function of research". Research is often treated as a secondary activity: either auxiliary (to teaching) or ancillary (as an appendix to routine commissioned tasks). This leads to a permanently fragmented system, blurred governance, conflicting policies and unsteady support.

Without changing the performers, it may be efficient to *structure* research for its own sake (with specific institutions and incentives common to all players, as Tunisia did when designing "national laboratories" selected for core support and compelled to periodical assessment). The idea is to develop a trust of diverse parts of the society in what research may (and should) offer: much more than the hazy and customary benefits usually referred to.

Among the good reasons to develop relevant and efficient research one may list:

- Taking seriously the sustainable and up to date training (or re-training) of executives and qualified staff (whose knowledge should not become obsolete within a few years).
- Giving credibility to a few labelled laboratories well equipped renowned and willing to deliver services to firms and the community
- Having at the state's disposal a pool of experts informed of the frontier knowledge and the world technological stakes when facing dubious decisions[15]. This may entail point-blank advice or regular watch surveys (in halieutics, health, environment… or about the state of the society)

15 Their network of international partners is an extra asset.

Moreover, research should be credited (and expected) to put forward:

- Strategic ideas towards recurrent problems. Examples are numerous about water management, plant breeding, environment protection, new energies… where significant progress is being made at forced march in laboratories and small innovative firms through the world. Sub disciplines like applied mathematics (modelling, statistics) have a large potential to be tapped.
- New resources for the country. Examples are marine natural resources (which remain largely to be investigated and exploited); water resources (which could be diversified and better managed); chemical novelties, like insecticides derived from plants, etc.
- Developing new capabilities for the launching of new branches of trade (ICTs is an example already cited, achieved in Tunisia and Morocco).

Research is worth being supported for itself, provided it is driven in a firm and wise way toward anticipating niches and innovations.

Science management is a promising activity that needs to be developed for its own sake by scientists and policy makers. They must join together, with a broad view of the scientific landscape and the social stakes. This means knowing the local scientific system with its structure and tensions. This entails knowledge of the present state of science and technological stakes through the world (with their probable advancement and changes in a near future). This needs also intensive links with international partners: it entails a responsibility of the world scientific community, and a commitment of developed countries for adequate cooperation.

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3. Applying the template

Our final section 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.

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[16] 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[17]. 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.

16 Ben Martin ….
17 Benoit Godin

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 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. Efforts 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 indicators (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 descriptors, especially about:
  - o 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);
  - o 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);
  - o 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") is carrying out research? Have they parallel activities (which kind)? 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 and 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[18].

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 involves 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

18 The template for such a questionnaire is available from Dr Waast

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).

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 co-operations, 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[19].

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.

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.

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

[19] CREST, University of Stellenbosch, has developed such a database on South African science since 1998 which allows it to conduct much more detailed field and institutional bibliometric analyses.

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.

Annexure 1: The coverage of agriculture and health in the template

Agricultural and health research systems in developing countries are often the main foci for development and capacity strengthening initiatives, given pressing needs to modernise subsistence farming to ensure food security, and equally strong needs to combat HIV/AIDS and malaria and other infectious and tropical diseases. It is therefore imperative that the agricultural and health research systems be adequately covered in the proposed template.

Agriculture

The Agricultural Science & Technology Indicators (ASTI) initiative is the most authoritative source of data and reports on agricultural R&D in developing countries. ASTI activities are led by the Knowledge, Innovation, and Capacity Division (KICD) of the International Food Policy Research Institute (IFPRI), a research centre of the CGIAR (Consultative Group on International Agricultural Research). IFRI is based in Addis Ababa, Ethiopia, with staff located at offices in Washington, DC and Rome, Italy.

An inspection of the on-line data products of ASTI (www.asti.cgiar.org) reveals a number of indicators that could strengthen Categories 6 and 7 in the template (i.e. S&T Human Resources and Research Funding). These are listed in Table 9, together with an indication of the 52 UNESCO study countries for which data are available.

Apart from providing statistical indicators the ASTI initiative can also provide both narratives and descriptors to augment the focus on and comprehension of agricultural R&D in developing countries. Two examples for Ivory Coast are given below. The narrative (taken from the relevant ASTI Country Brief) provides a brief overview of the history of government-based agricultural research in that country, and the descriptor component (taken from the ASTI Snapshot Data) lists the main crops and livestock items in Ivory Coast.

Example of narrative

A Short History of Government-Based Agricultural Research in Côte d'Ivoire

A number of CNRA's research institutes were originally established during the 1890s as "experiment gardens." After Word War I, most of these gardens evolved into experiment stations that focused on a very small number of crops. When the French colonies throughout West Africa gained political independence in the late 1950s, the French regional research system collapsed. At the time of independence, most of Côte d'Ivoire's agricultural research facilities were managed and staffed by the French tropical research institutes, and, given the lack of trained staff to continue these programs, bilateral agreements were made whereby the French institutes continued to manage the stations with joint funding.

Most of the former French colonies sought to nationalize their agricultural research systems in the late 1960s and early 1970s, but Côte d'Ivoire chose to continue close collaboration with institutes such as ORSTOM and the Study and Research Group for Tropical Agricultural Development (GERDAT, CIRAD's predecessor) for a much longer period of time. By the 1980s and 1990s, further institutional changes occurred representing a departure from earlier trends. CIRT was created in 1981 to conduct research on the processing of agricultural products; IDESSA followed in 1982 and gradually took over French local research activities and facilities in the savanna zone.; in 1992, IDEFOR replaced various existing French institutes conducting forestry research; and in 1998, CIRT, IDESSA, and IDEFOR were merged to become CNRA. CRO, established in 1958 by ORSTOM, still operates under the same name.

Sources: Roseboom and Pardey (1994), Traoré (1999) and Gage et al. (2001).

ASTI Country Brief No. 4, April 2003

Example of descriptor

Main crops: cotton (14.1%), oil palm (11.7%), vegetables (7.3), coffee (6.1%), and cocoa (6.1%)
Main livestock items: sheep and goats (20.5%), beef (19.1%), and pastures and forages (5.7%)

www.asti.cgiar.org/snapshots/cote_divoire.aspx

Health

The Global Forum for Health Research, established in 1998 in Switzerland as an independent international foundation, aims to track research resources for health world-wide. In their latest annual monitoring report (Burke & Matlin, 2008)[20], a Report Card for Health R&D is introduced, in order to strengthen the regular review of health research targets and commitments, and to track the progress made towards meeting these targets. Specifically, the Global Forum will develop the Report Card systematically in the coming years, collecting, analysing and reporting the data that is available and working through advocacy, partnerships and catalytic roles to secure the development of information systems for producing such data where it does not yet exist (Burke & Matlin, 2008: xxix).

It is therefore imperative to consider in the proposed template also the indicators listed in the Global Forum's Report Card (Table 8).

Table 8: Report Card for Health R&D, developed by the Global Forum for Health

A. All Countries
A-1. National R&D total investment as a percentage of GDP
A-2. National R&D for health as a percentage of GDP
A-3. National R&D for health as a percentage of national health investments
A-4. National R&D for health as a percentage of total R&D
B. High-income countries
B-1. Gap between actual ODA investments and commitment to invest 0.7% of GNI on ODA
B-2. Gap between actual annual increase in ODA and commitment to double aid between 2005 and 2010 – an extra US$ 50 billion worldwide and US$ 25 billion for Africa
B-3. Gap between actual ODA investments in R&D for health and target to invest 5% of health ODA in R&D for health

20 Burke, M.A. & Matlin S.A. (eds.) 2008. Global Forum for Health Research, *Monitoring Financial Flows for Health Research 2008.* Global Forum for Health Research, Geneva, Switzerland.

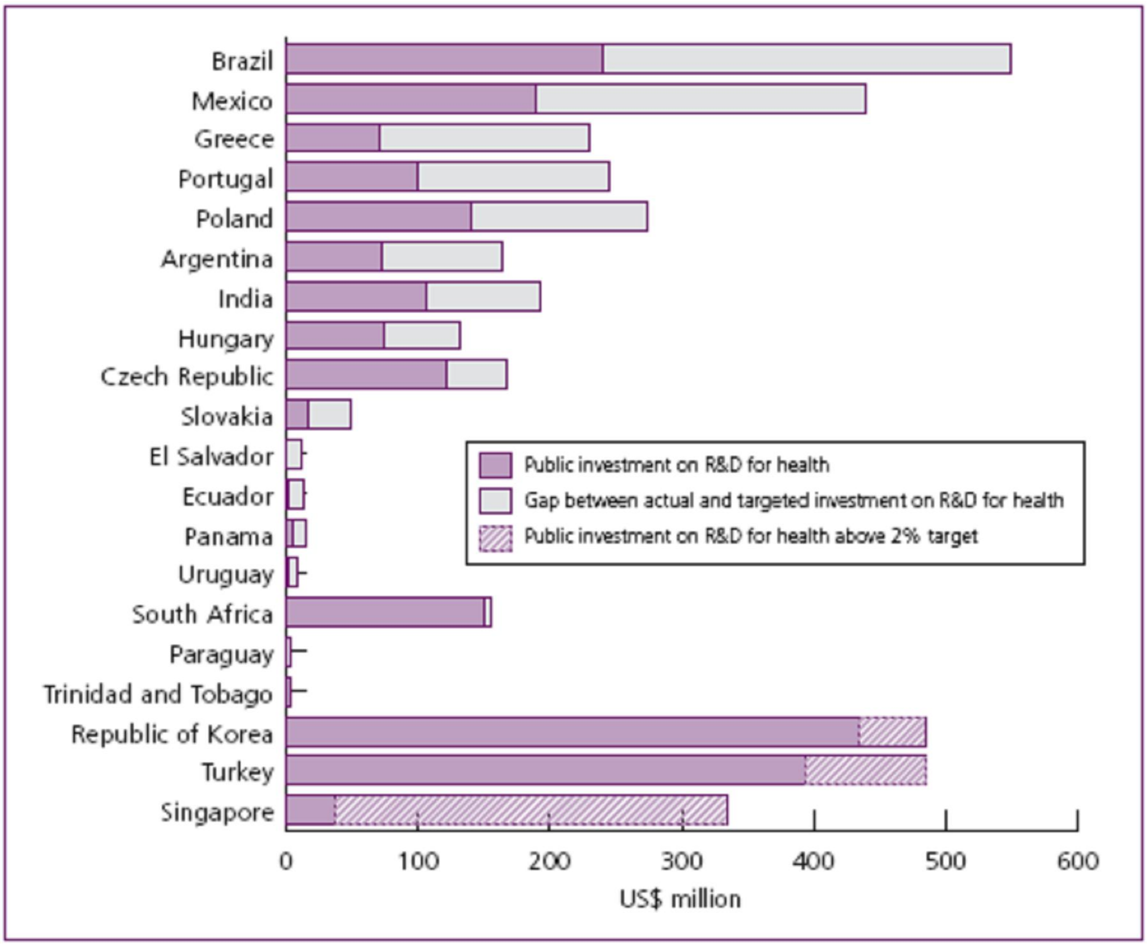
Table 8 Continued

C. Low- and Middle-income Countries
C-1. Gap between actual investments in health and target to spend 15% of domestic public spending on health
C-2. Gap between actual investments in R&D for health and target to spend 2% of national health budgets on health research
D. Global Health Initiatives and development agencies
D-1. Gap between actual investments and commitment to invest 5% of overall health investment portfolios of Global Health Initiatives and development agencies to support research capacity of countries, dissemination of research findings, and management of knowledge.

Burke & Matlin (2008:83, Box 4.1.)

A selection of at most two indicators from A-1 to A-4 in the Report Card can be included in Category 7 in the Template (Research Funding), to augment the profiling of the health research sector. Aspect C-2 of the Report Card can be included as a descriptor, also in Category 7 of the Template, as it summarises the country's progress made towards spending 2% of the national health budget on health research (see Figure 12).

Figure 12: **Gap between actual and 2% target for public investments in research for health in low- and middle-income countries, 2005 estimates**



Burke & Matlin (2008:107, Figure 4.14)

It is not possible at this stage, based on the web-based resources and products of the Global Forum for Health (www.globalforumhealth.org), to comment on the availability of Report Card data for the 55 UNESCO countries. Indications are that data currently exist only for a limited number of countries.

Table 8: ASTI agricultural R&D indicators and UNESCO study countries (out of 55) for which data is available

R&D indicators	ASTI Source	Region			
		African region	Arab region	Asia region	Latin American and Caribbean Region
Indicators to consider in Category 6 in Template (S&T Human Resources)					
Total agricultural researchers (FTE) in public sector	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2003)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)
Total agricultural researchers (FTE) in private sector	Snapshot Data Country Brief	Ethiopia (2000), Ivory Coast (2001), Kenya (2000), Malawi (2001), Uganda (2000), Zambia (2000)	Jordan (2003), Syria (2003),	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Philippines (2002), Sri Lanka (2003), Vietnam (2003)	
% distribution of public sector agricultural researchers by highest qualification (PhD, MSc & BSc)	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2003)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)

Table 8 Continued

R&D indicators	ASTI Source	Region			
		African region	**Arab region**	**Asia region**	**Latin American and Caribbean Region**
Indicators to consider in Category 6 in Template (S&T Human Resources)					
% distribution of public sector agricultural researchers by commodity focus (crops, livestock, natural resources, fisheries, forestry, post-harvest, other)	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2003)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)
Support staff to researcher ratio	Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Philippines (2002), Sri Lanka (2003)	Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)
Women as % of public sector agricultural researchers	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2001), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2003)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)

Table 8 Continued

R&D indicators	ASTI Source	Region			
		African region	Arab region	Asia region	Latin American and Caribbean Region
Indicators to consider in Category 6 in Template (S&T Human Resources)					
Public researchers per $100 million agricultural output (AgGDP)	Indicator included in the ASTI Timeseries database				
Indicators to consider in Category 7 in Template (Research Funding)					
Total public R&D expenditures (local currencies)	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2002)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)
Total private agricultural R&D expenditures (local currencies)	Snapshot Data Country Brief	Ethiopia (2000), Kenya (2000), Malawi (2001), Uganda (2000), Zambia (2000)	Jordan (2003), Syria (2003)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2002)	

Table 8 Continued

R&D indicators	ASTI Source	Region			
		African region	**Arab region**	**Asia region**	**Latin American and Caribbean Region**
Indicators to consider in Category 7 in Template (Research Funding)					
Total public agricultural R&D expenditures (international dollars - PPP)	Snapshot Data Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2001), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2002)	Argentina (2006), Chile (2006), Colombia (2006), Costa Rica (2006), Mexico (2006), Panama (2006)
Total private agricultural R&D expenditures (international dollars - PPP)	Snapshot Data Country Brief	Ethiopia (2000), Kenya (2000), Malawi (2001), Uganda (2000), Zambia (2000)	Jordan (2003), Syria (2003)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Pakistan (2003), Philippines (2002), Sri Lanka (2003), Vietnam (2002)	
Total public agricultural R&D expenditures as % of agricultural output (AgGDP)	Country Brief	Botswana (2001), Burkina Faso (2001), Ethiopia (2000), Ghana (2001), Ivory Coast (2000), Kenya (2000), Malawi (2001), Mali (2001), Senegal (2001), Tanzania (2000), Uganda (2000), Zambia (2000)	Jordan (2003), Morocco (2002), Syria (2003), Tunisia (2002)	Bangladesh (2002), Indonesia (2003), Malaysia (2002), Nepal (2003), Pakistan (2003), Philippines (2003), Sri Lanka (2003), Vietnam (2002)	Argentina (2006), Chile (2006), Colombia (2006), Mexico (2006)

Non-listed countries = No data or data not updated since the mid-1990s

Annex 2: List of 55 countries in the Meta Review

Asia (10): Bangladesh, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam

Latin America (9): Argentina, Bolivia, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, Venezuela

Caribbean (6): Costa-Rica, Cuba, Jamaica, Panama, Trinidad & Tobago.

Arab countries (12): Algeria, Bahrain, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates

Africa (18): Botswana, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Lesotho, Malawi, Mali, Namibia, Rwanda, Senegal, Sudan, Tanzania, Uganda, Zambia, Zimbabwe

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