An Assessement of Science and Technology Capacity building in Sub-Saharan Africa

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ATPS is supported by a growing number of donors including the International Development Research Centre (IDRC), the Carnegie Corporation of New York, the Rockefeller Foundation, the World Bank, the OPEC Fund, Ford Foundation, Coca-Cola Eastern Africa, the African Development Bank, *Info*Dev, and the Royal Dutch Government.

List of Abbreviations and Acronyms

AAS	African Academy of Sciences
AAU	Association of African Universities
AERC	African Economics Research Consortium
AFREPREN	African Energy Policy Research Network
AIHTTR	African Institute of Higher Technical Training and Research
ANSTI	African Network of Scientific and Technological Institutions
ARCEDEM	African Regional Centre for Engineering Design and Manufacturing
ARCT	African Regional Centre for Technology
ARIPO	African Regional Intellectual Property Organization
ARSO	African Regional Standards Organization
ATPS	African Technology Policy Studies Network
CAPAS	Coordinated African Programme of Assistance in Services
CGIAR	Consultative Group on International Agricultural Research
COHRED	Council of Health Research for Development
GDP	Gross Domestic Product
GNP	Gross National Product
IDRC	International Development Research Centre
IHPP	International Health Policy Program
NASO	Network of African Scientific Organizations
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USHEPiA	Universities Science, Humanities and Engineering Partnerships in Africa

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1. Introduction

Since the 1979 Vienna Conference on Science and Technology for developing countries, international development agencies as well as national governments have attempted several initiatives for the economic development of the African continent. The results are mixed. There have been pockets of outstanding successes, but also many abandoned expectations. Regretfully, it is the catalogue of failed efforts and attendant obstacles that has dominated the presentation of the state of science and technology development in the continent. The negative reporting has been so persistent that it has taken on a life of its own, sometimes crippling the enthusiasm and morale of otherwise talented innovators, daring investors, and budding scholarly communities. The pessimism, however, has often been exaggerated. An array of accomplishments under challenging circumstances can also be interpreted to produce a more optimistic characterization of the continent's potential, pointing to the prospects and opportunities rather than to the failures and obstacles. Although the technological order between the developed countries and the developing countries has greatly improved in many countries in Asia, Latin America and Eastern Europe, this is not the case in Africa where the gap between the two groups continues to grow.

The African Governors of the World Bank concluded in 1998 that 'Africa is a continent rich in natural resources but lacking the capacity to transform that potential into a standard of living that would enable the African people to become full partners in the global economy'[1]. Indeed, the present economic profile of sub-Saharan Africa is worrying: the continent is poorly integrated into the innovation-based global economy; its share of global trade fell from 3 % in the mid 1950s to 1 % as of 1997[2], and more recently it is estimated to be falling further (Adubifa, 2000). The World Bank projects growth rates of the African economy to increase modestly to only 3.3 % by the year 2000. Export growth is expected to advance by 6.3 % in 2000 (4.6 % if South Africa and Nigeria are excluded); and the continent will continue to be highly vulnerable to commodity prices and global economic developments[3].

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[1] Partnership for Capacity Building in Africa: Strategy and Business Plan, Report of the African Governors of the World Bank to Mr. James D. Wolfensohn, Sept. 1998.

[2] Business Africa, May 1-5, 1997; The Economic Intelligence Unit.

[3] Africa: Policy Outlook 2000, Africa Policy Information Centre, Jan. 2000.

Section 2 of this report reviews the status of science and technology capacity in sub-Saharan Africa. It has been necessary to describe the science and technology systems of the countries through subjective interpretation of scattered, incomplete, and sometimes inaccurate or totally missing data on performance indicators. Comparison of available data was equally difficult since data sources and quality across the continent were not standardized. Nonetheless, the study provides a synthesis of policy analytical documents on the status of science and technology in sub-Saharan Africa, supplementing the sparse published data with information from discussions with donor representatives and locally based practitioners.

Section 3 reviews experiences in science and technology capacity building in sub-Saharan Africa. It discusses the elements that have contributed to the successes of some of the national efforts, as well as the factors that have limited the ability of other initiatives to achieve expected impact.

In recommending a regional strategy for the development of science and technology capacity, especially the capacity for undertaking research and improving its social benefits in sub-Saharan Africa, Section 4 is a review of lessons from past efforts. Section 5 proffers a number of specific recommendations, with some addressed to national governments and others to the World Bank and its partner development institutions, as well as to other donors supporting African development.

2. Status of Science and Technology in SSA

2.1 Historical context

Researchers on African economic development generally confirm that credible data on science and technology indicators are difficult to collect. Available data give skewed results when aggregated, and are sometimes incompatible with physical evidence. While South Africa, for example, is part of sub-Saharan Africa, its science and technology indicators are considerably higher in value than those of the rest of the continent. Major international handbooks that regularly publish comparative data on global development (including UNDP's Human Development Report, UNESCO's Statistical Yearbook, and National Science Foundation's Science and Engineering Indicators) are usually unable to provide complete data in reporting on African countries. Yet the availability of such data and the credibility of their sources would facilitate national planning and assist external donors to make wise investment decisions.

Africa has never had a clear definition nor a comprehensive characterization of its state of science and technology development. Several studies have been carried out by locally-based researchers to capture the thrust, scope, implementation, and outcomes of the many initiatives that are internally or externally generated, and to describe their effects in building a science and technology capacity at the national level. The outcome of many such studies generally fall short of expectation because:

- researchers are unable to find appropriate statistical data;
- the research objective is poorly defined;
- the scope and coverage of research activities are too wide for the available funding;
- research methodology and data gathering are not designed to allow comparison across countries; and
- research efforts do not benefit from rigorous peer review.

2.2 General Characteristics of the State of Science and Technology

Sub-Saharan Africa's internal science and technology capacity lags behind the continent's economic potential. This realization is compelling African countries to take the science and technology sector more seriously, leading to calls from many countries for urgent international assistance to help them develop their incipient capacities and harness their potential more systematically. A crucial beginning of this new willingness to act is to forge an understanding of the existing strengths and assets, which should form the cornerstone of new and innovative initiatives.

In the 1960s and 70s the international development assistance community gave a lot of emphasis to deepening Africa's science and technology capacity. It supported both government and academic institutions, but not the private sector.

The results (presented below) are below expectation:

- Science and technology sectors and professions are still in their infancy and not strong enough to compete globally; universities have suffered from inadequate funding for long periods and their academic standards have declined in many cases.
- Science itself, as a field, is not fully appreciated since it is not introduced into early education.
- Apart from a few groups and individuals scattered across the continent, the academic communities are largely isolated from their global colleagues.

Under these conditions, there have been limited private investments in technological development or scientific applications. Sub-Saharan African countries have not acquired adequate scientific and technological capabilities to meet the challenges of globalization, particularly the attendant international negotiations in the economic, financial, and environmental regimes.

A breakdown of global expenditure on science and technology shows that the high-income OECD countries account for about 85 % while Africa's share is only about 2 %.[4] Furthermore, the distribution of the world's scientific and technological outputs as measured by indicators of scientific publications and registered patents shows considerable disproportionality: 80 % of publications are owned by the highly industrialized countries plus India, while 96 % of the world's patents are registered in the United States, Japan and Western Europe. While capital flows to developing countries as a whole reportedly averaged 3.2 % of GDP during the 1990s, African countries averaged only 1.9 %. Africa's share of the total foreign direct investment flowing to developing countries was a mere 3 % in 1997[5]. The number of African scientists and engineers in professional practice is also considerably lower than the world average, on population basis. The continent furthermore accounts for only 0.8 % of the world's listed peer-reviewed publications, and only 0.2 % of registered patents.

Results of science and technology policy research and promotion of policy dialogue in some of these countries, funded by IDRC and the Carnegie Corporation of New York over the past 10 years, show that the level of public sector awareness has been greatly elevated, and there is increasing collaboration between government functionaries and academicians in addressing science and technology development issues. Some countries are improving and expanding their channels of communication between scientists and technologists, government officials and advisers, parliamentarians, and service sector practitioners. For example, Zimbabwe Institute of Development

[4] see UNESCO, World Science Report 1996
[5] Business Africa, May 1-5, 1997, The Economic Intelligence Unit

Studies has convened working groups of stakeholder representatives for each of the economic sectors to deliberate on sectoral performance, and to formulate strategies for strengthening these sectors and optimizing their potential. This has been possible with funds from the Carnegie Corporation of New York.[6]

Several opportunities for science and technology development are beginning to appear in the horizon, and many countries are determined not only to use them effectively but also to enlarge them in order to accelerate national development. Some of these opportunities are:

- a new generation of students is emerging as university enrollment soars and competition for excellence increases;
- literacy levels are rising in all countries, elevating the national capacity to facilitate scientific applications and participate more effectively in national development;
- skilled entrepreneurs with talent and dedication are growing in number, and equally increasing their global outreach through the new information and communication technologies;
- democracy, accountability, and the rule of law are spreading rapidly across the continent, and becoming entrenched in irreversible ways in many countries where such prospects could not be contemplated only a few years ago;
- with democratic dispensation taking root and under the pressures of globalization, many countries are beginning to open their formerly closed markets; and
- new wireless technologies and mobile computing devices are enabling ambitious institutions and civil society organizations to leapfrog into the digital world, avoiding the high costs previously associated with traditional computer and telecommunications infrastructure.

[6] This consensus-building mechanism has helped the nation to rally efforts for the development of science and technology. The national parliament is now paying attention to this and its Budget Committee, led by the Deputy Speaker, schedules meetings with these working groups before annual budget considerations. The Ministry of Science and Technology is allocating some resources to boost the work of the working groups. This initiative by the researchers has led to the preparation of Zimbabwe's first-ever draft of a National Policy on Science and Technology.

3. Building Science & Technology Capacity

This section discusses experiences in building science and technology capacity in sub-Saharan Africa. Perhaps the best example is the Green Revolution initiative pioneered by Ford and Rockefeller Foundations. Their funded research for the production of high-yielding rice and maize varieties led to the establishment of the Consultative Group for International Agricultural Research (CGIAR). Similarly, the African Economics Research Consortium (AERC) was initially launched by IDRC, and later supported by the Rockefeller Foundation, to strengthen economic management in sub-Saharan Africa. It is now a flourishing capacity-building research network funded by a consortium of donors.

These successful models point clearly to the kind of framework that effectively builds and sustains capacity. The framework is characterized by:

- funding commitment to sustain the initiative over the long term, and beyond the threshold;
- sound institutional management under strong scientific leadership; and
- elimination of resource uncertainties regarding scientific careers, research facilities, access to the international research system, and a conducive academic environment.

3.1 Regional Initiatives

Regional initiatives concentrated mostly on institution-building, but some operated as networks housed in existing institutions. Apart from the CGIAR institutions and the AERC network, other successful programmes include the African Technology Policy Studies Network (ATPS), the Coordinated African Program of Assistance in Services (CAPAS), the Council on Health Research for Development (COHRED), the International Health Policy Program (IHPP), and the Universities Science, Humanities, and Engineering Partnerships in Africa (USHEPiA). All these initiatives receive their entire funding from donors.

While the initiatives have been largely successful they have also suffered, to varying degrees, from certain weaknesses:

- capacity building activities did not always emphasize scientific quality;
- programmes took on wider scope than optimal, thereby losing thematic coherence;
- lack of clarity regarding financial and administrative support for the host institution, especially as some donors only provided programme support and not core support for the institutions;
- donor support waned just when it became necessary to consolidate the emerging gains of the initiative.

The African Academy of Sciences (AAS) is a special case of an institution in the forefront of building scientific capacity in Africa, but which continually struggles against odds to accomplish its mission. It enjoyed strong donor support at its founding because the need for such an organization was clearly apparent. Its objectives were laudable and its programmes compelling. It achieved outstanding success with its regular publication of a world-class scientific journal-*Discovery and Innovation.* However, its programmes rely almost totally on external funding which has usually been below threshold.

3.2 Less Successful Regional Initiatives

Three examples of important regional initiatives that did not achieve expected impact are described below:

1. The USAID's Programme of Science and Technology Cooperation sought to support research in developing countries in collaboration with US scientists (or scientists from other developed countries who would have to bear their own portion of the research costs). This highly competitive international grant programme made no allowances for the weak scientific infrastructure of the institutions of the African applicants, nor for their lack of access to current knowledge in their research fields. Very few African scholars benefited from the grant scheme. Others expressed frustration at the disadvantages that they faced in the competition against more advanced developing regions.
2. A number of intergovernmental science and technology institutions were established by Member States in the late 1970s when African leaders were full of optimism and had liberal access to donor resources for development. These included:
   - The African Regional Centre for Technology (ARCT)
   - The African Regional Centre for Engineering Design and Manufacturing (ARCEDEM)
   - The African Regional Standards Organization (ARSO)
   - The African Regional Industrial Property Organization (ARIPO)
   - The African Institute for Higher Technical Training and Research (AIHTTR)

The respective mandates of these institutions were unrealistic with respect to available funding, staffing and operating facilities. Beyond initial funding, the Member States gave little attention to science and technology development, especially as their national economies took an unexpected downturn. The institution-building efforts also took on political dimensions by which the management, staffing, service conditions, and international status of the institutions were to be politically negotiated. Without adequate core funding most of the institutions could not be sustained, and their skilled professional staff departed. This quickly led to loss of project funding from donors.

AIHTTR was closed down within ten years. ARCEDEM's elaborate technical and mechanical facilities are largely idle, and ARCT does not have the resources to play a regional role anymore. Between these three organizations a lot of capacity that was built in the initial years has hardly been put to productive use. ARSO and ARIPO are still functioning, but are barely effective as regional engines for development.

3. The Association of African Universities (AAU) has a membership of more than 140 institutions across the continent. It has made efforts in recent years to promote capacity building for scientific research in the universities. It established a programme to market top research proposals that are developed and submitted jointly by inter-university collaboration between two or more institutions. Forty two such proposals were submitted for experts' review in 1998, out of which the best seven were presented to the meeting of donors to African higher education. Although the donors acclaimed these proposals to be rigorous and compelling, they did not agree to a proposed pool-funding mechanism. They merely endorsed the proposals as worthy of support, and advised the applicants to seek funding individually from interested donors. This raised concerns among African scholars about the conflicting signals that seemed to be emanating from the donor community.

3.3 National Projects

At the national level, research systems continue to grow slowly, mostly with the support and advocacy of donor agencies, in contrast to national inertia. Previous efforts have created isolated layers of successful scientific research, but lacking a broad base of competent mid-level technicians (qualified laboratory assistants, analysts, statisticians and data processing specialists, equipment maintenance specialists, etc.) all of whom play important roles in research.

The national research systems are generally characterized by:

- instability of support to research and development;
- lack of political commitment at top governmental levels;
- low public awareness of the need and importance of scientific and technological capacity (mostly due to the absence of a science-based culture); and
- poor recognition and reward for achievements in science.

It is relevant to note that no single indicator is available yet for measuring science and technology capacity in Africa. Only a detailed assessment in a given country can reveal the real and present level of its research capacity, and properly characterize its structure. National experiences are reviewed below under three of the most common models:

1. Support for Individual Scientists

This modality has had limited success in countries like Nigeria, Ghana and Sierra Leone. Although the individual scientists received personal benefits that upgraded their skills or expanded opportunities for international exposure, the impact of the projects were hardly felt beyond their immediate environment. Financial support from donors did not usually anticipate the requirements for institutionalization of project outcomes, nor did it provide specifically for project outreach that would multiply the effects of capacity strengthening.

2. Support to Universities and Research Centers

The number of scientists in African universities often increased more rapidly than the available funding for research. But, regardless of the amount of resources available, a number of practical considerations continue to limit African efforts to increase research capacities through institution building. Among them are the following:

- universities and public research centres lack adequate numbers of technicians, specialists, and qualified managers to support the desirable level of research
- universities often tend towards the European tradition which pursues scientific knowledge without entrepreneurial enthusiasm; they do not generally emphasize applied research that would interface closely with the private sector. Their academic culture promotes scholarly research and publication, but it is not geared towards business development or industrial applications
- the trend of diminishing funds per researcher has intensified in the last decade
- the imbalance between human and financial resources has exacerbated another problem: the cost of maintaining research infrastructure (laboratories, equipment, physical plant, etc.) has risen sharply, leading to their stagnation, degradation and obsolescence
- research teams do not always have functioning basic facilities, access to current literature, compatible teaching and administrative load, nor the cooperation of their institutions
- because the key ingredient-*funding*-is often not reliable nor programmed for long term support, research teams easily become isolated; they need to be nourished by external contacts at conferences, in networks, and by exchanging research fellows
- nationally-sourced funds (especially government subvention) are applied mainly to staff salaries. It is the external funds that usually support research projects. This leads to the tendency to load excessive numbers of under-qualified workers on to the research fund
- promotion policies and rewards are more favorable to administrative and managerial functions than for research and scientific achievements. This leads inevitably to high rates of turnover in research staff, which in turn undermines efforts to develop a cadre of skilled and experienced researchers.

3. Support for Networks and Promotion of Networking

In an initial attempt to identify success factors in research networks, a 1998 colloquium in Bellagio, Italy, identified a number of critical elements. These were reported by Prewitt (1998) to include:

- balancing open membership with quality
- good governance system
- common needs assessment with shared ideas about problems and solutions
- financial stability
- adequate project management capacity
- institutional ownership of the research programme

Examples of strong and successful networks that are coordinated from within the region are ATPS, AERC, and USHEPiA, all of which have been described as regional initiatives. Others include the Africa Energy Policy Research Network (AFREPREN). They all enjoy, for the most part, adequate donor funding to sustain their research programmes. They have also all managed to keep administrative costs low by remaining as programmes within existing institutions. In USHEPiA particularly, the enthusiasm of participating institutions, researchers and their joint supervisors, as well as the effective linkages at the senior management level of participating universities have contributed enormously to the network's outstanding impact. A distinguishing feature of the programme is the provision of re-entry grants to visiting researchers to enable them upgrade their local research environment upon returning home.

Other important but less successful networks include the AAS's Network of African Scientific Organizations (NASO), the African Network of Scientific and Technological Institutions (ANSTI), and several discipline-focused regional and sub-regional networks. The most crucial limitation that these face is sustainable funding.

3.4 Capacity Building through Industrial Development

The countries of sub-Saharan Africa have not explored the full potential of industrial manufacturing as a vehicle for building scientific and technological capacity. Most local industries are still in their infancy and do not generally have the risk capital to engage in basic research and technological innovation. On the other hand, the multinationals normally conduct research and development at their parent companies, leaving African subsidiaries to acquire technology through basic training, production, and quality control functions.

In South Africa, which is the most technologically advanced country in the region, efforts are underway to convert some of the existing technological capacities which were built under military and nuclear energy programmes into commercial production capacities for public benefit. This link between the public and private sectors will facilitate rapid upgrading of technological skills in industry.

The countries of the region are beginning to discover what works and what doesn't with respect to industrial development as shaped by the national science and technology system. They are finding that apart from financing there are four other parameters that need to be firmly in place to assure successful transition of their economies from rural agrarian to modern industrial. These parameters are policies, legislation, institutions and training.

Even though case studies would be necessary to determine how well the industrial sector has fared with respect to the national science and technology policies and legislations, there are already a number of success stories that can inspire other countries in similar circumstances. These are:

- Morocco, although not part of sub-Saharan Africa, has demonstrated that careful and targeted planning for the application of science and technology to socio-economic development would reap rich dividends. According to Jugessur (1998) the country has adopted modern technologies like green house technology, tissue culture and overhead irrigation methods to meet national food requirements and produce other goods and services.
- Mauritius, a country of only one million people, is taking advantage of its high literacy rate, political stability and the hard-driving work ethics of its people to achieve an annual growth rate of about 6 %. Its industrialization process is being driven by a well-focused set of

science and technology policies that include very attractive incentives. The country seeks to become a leading African centre for micro informatics technology.

- Governmental collaboration with the private sector in Zimbabwe has promoted the development of solar photovoltaic technology which is now being rapidly commercialized throughout the country. This low cost energy system will find wide applications in homes, schools and farms. Zimbabwe's ATPS chapter is taking a leadership role in preparing the country's science and technology policy and planning framework while its Scientific and Industrial Research and Development Council is mobilizing the country's research potential for effective utilization.

4. Lessons From Past Efforts

Stakeholders in African development, particularly the donor community, have been increasing their search for lessons of past experience in order to guide their future investment in the science and technology sector. They appear keen to find out what impact has been achieved by these past efforts (both public and private) to build capacity during the past several decades. No overall assessments are available. However, there is enough anecdotal evidence to suggest that the impact has been below expectation. Many of the following experiences address the performance of external assistance:

- The skills and capacities that have been developed have not been harnessed purposefully to maximize their potential. Opportunities for their direct application were often missing, as external assistance that built the capacity did not always extend into such long-term practical applications that would be found in the private sector. Generally, the capacity building also was not a direct result of private sector demand.
- External assistance came in various forms from many sources, usually addressing different aspects of the process for developing a science and technology system. Donor collaboration and national programming of assistance were not given sufficient attention, leading to uncoordinated implementation of similar activities, and over stretching the limited human resources available for specialized functions. Generally, this led to a reduction of the possible impact of the projects as initially conceived.
- The models used by external assistance to address science and technology issues were seldom able to build adequate capacity to tackle the problems confronting the countries. Assistance that was provided consistently over the long-term and targeted at a specific need has been shown to achieve better results. An example is the CGIAR model for agricultural research that is well-funded by a consortium of donors and devoted for more than 30 years to the development in Africa, of new and improved varieties of seeds and food crops.
- Centers of excellence were sometimes established to build capacity, but these later required high maintenance costs which the beneficiary countries could not afford amid competing social needs.
- Where building of research capacity has been the objective, the final product has often been a research report or journal publication. The results of such research were not transferred to industry or commercialized through patents. A general and recurring finding of policy research across the continent is that much of the previous efforts to build capacity

did not link projects to end users. It can therefore be said that capacity-building initiatives sometimes met narrow objectives and did not produce sustainable development.

- Past efforts had focused too heavily on studying the economic profiles and their indicators without adequate specificity of science and technology components of those indicators. This is probably why analytical data on scientific and technological performance of individual countries have been so hard to find.
- Foreign firms operating in African manufacturing industry usually source their technological and engineering inputs from abroad, and also carry out research and development in their parent organizations. They therefore built local capacity only for equipment maintenance and quality control.
- Global trends in technological advancement and application have not always allowed opportunities for the infant science and technology systems in sub-Saharan Africa to impact on domestic economies. In addition, the few scientists and scholars who acquire critical capacity are often drawn away from local needs towards global issues.
- It is fair to say that after so many years of training, fellowships and research support, a large number of individuals have been strengthened in their personal skills for scientific endeavor. But the impact of all this is not quite institutionalized. This is a systemic weakness that is proving difficult to overcome. Governments and their external collaborators would need to form a stronger partnership to implement modalities that make all development assistance more effective through appropriate institutionalization.
- Support for science and technology development is still facing a dilemma of choosing between alternative models of building capacity. External assistance would like to achieve rapid results, but is also concerned that previous investment did not point clearly to a specific model as the strategy of preference.

For example:

- in choosing between support for science versus support for technology in Africa, the extent to which a country should devote resources to basic research is always difficult to estimate. Longer-term strategy requires the development of capabilities to assimilate and adapt foreign technologies, to produce engineering designs, and to carry out consulting services.
- the choice between investing in policy research or in technological research will vary from country to country. Very little technological research appears to be going on now in most countries, partly because its costs far exceed the resources needed to pursue policy research.

5. Recommendations

Recommendations for a Regional Strategy for the Development of Science and Technology Capacity in Sub-Saharan Africa

It is recommended that a regional strategy should seek to simultaneously achieve the following goals:

- Strengthen internal capacity of government machinery to address science and technology effectively and integrate its system into the national development and planning strategies. Science and technology policies need to be explicit, well articulated, and integrated into the overall national economic policy framework.
- Create awareness among stakeholders about the need to invest in science and technology, the potential benefits to society, and the opportunities that become available for utilizing it to foster social and economic development.
- Promote consensus building for science and technology policy and planning through the establishment of working groups of appropriate public and private sector representatives.

Operationally, implementation of the strategy should be complemented by national action. While it is recommended that different approaches be targeted to meet the needs of selected countries, a common need for all of them is the use of structured formal training to nurture a cadre of scientists and young scholars who can keep the countries engaged in global intellectual production.

The following three elements are proposed as possible mechanisms of intervention:

- a comprehensive study to collect and analyze credible science and technology data
- a programme of the Millennium Science Initiative
- specific programmes in groups of countries

5.1 Study to Collect and Analyze Science and Technology Data

There is a chronic lack of statistical data to describe the characteristics and performance of sub-Saharan Africa's science and technology sub-sector. Building a dynamic system for the development of the sub-sector requires considerable, but not insurmountable, investment. However, it should begin with the collection and analysis of baseline data as well as time-series measurement of the indicators that would describe the profile of sectoral progress and development. Where information is scanty and indicators for assessment are difficult to measure, the paucity of data increases the risks for investment decisions. This has been the case in sub-Saharan Africa.

Provision of factual data and quantifiable information will not only enhance the quality of analysis of science and technology parameters for sub-Saharan Africa, but it would also facilitate a more realistic comparison of development potential and characteristics among its countries, and between them and their counterparts in other developing regions of the world. Such comparisons would also assist African countries to identify and select more appropriate strategies based on similarities (or otherwise) of their science and technology profiles with those of more advanced developing nations whose efforts have yielded fruit.

Most countries of the region do not have the appropriate tools and personnel trained to collect and analyze the required data properly. The World Bank should lead efforts to initiate the appropriate process in its client countries, working with the governments and urging them to involve the private sector and academia in the programme.

5.2 The Millennium Science Initiative

Representatives of sub-Saharan Africa's scholarly community are investigating the efficacy of establishing vibrant research programmes under the Millennium Science Initiative (MSI) that is being fiercely promoted in Latin America by the World Bank. Several options are available, each of them carrying different risks and opportunities.

For the MSI to make a significant impact in Africa, especially in meeting its primary objectives of 'promoting frontier research and educating the best scientific talent in developing countries,' it will be necessary for its programmes to involve a sizable number of African research scholars and scientists, to nurture a modest number of research centres or units in specific priority disciplines, and to receive the committed support of the respective national governments.

Financing the selected centres for the MSI programmes would be a challenge unless there is adequate long-term commitment of research funds from external donors. National governments can be persuaded to give firm political support and recognition. Relatively wealthy countries may find it possible to also provide necessary resources to fund the MSI institutes or centres, but it is doubtful if many of the other countries would be willing to take new loans (as expected by the World Bank) to execute the MSI programmes.

It is therefore recommended that the World Bank and the African Development Bank jointly assume the responsibility of providing the resources to initiate model MSI institutes and, further, of mobilizing donor collaboration to assure the sustainability of selected centres over a 10 year period, at the minimum.

5.3 Specific Programmes at the Country Level

The objectives and suggested modalities for implementing six types of activities are described below:

5.3.1 Promoting Public Awareness and Advocacy

There is need to increase public awareness amongst countries of the importance of science and technology in the context of efforts to modernize national economies; improve national security; participate in international trade; strengthen the base for economic and social development; employment opportunities; and wealth creation. Countries need strong professional associations to guide, advocate, set standards, and regulate the practice of their professions in the scientific and technological fields. They also need to introduce science into early education.

5.3.2 Promoting Science and Technology Policy Research

In general, scientific and technological research in sub-Saharan Africa has been directed mostly towards agriculture, particularly the production of food crops. Now that several African governments are beginning to recognize the imperative of technology as an important tool for pursuing their development goals, and are also willing to embrace its potential, they would need an improved analytical framework of information to enhance their ability to make critical decisions and investment. Policy studies in science and technology can help to illuminate the gaps that must be addressed and provide a practical road map to guide various stakeholders as they contemplate next steps.

5.3.3 Building Capacity to Foster National Science and Technology Systems

Countries need to establish science and technology working groups as vehicles for responsible national dialogue among key stakeholders. Immediate benefits would include better articulation of ways in which science and technology might be applied effectively. External assistance should collaborate with host governments to create policy dialogue mechanisms. The assistance should also contribute technical expertise to backstop these initiatives which should facilitate the establishment of effective collaboration between policy makers, scientists and technologists, and the private sector. External assistance may also be able to assist countries to establish a funding mechanism, possibly with development banks, to be dedicated to national science and technology development. Other vital initiatives would include the strengthening of the policy, supervisory and regulatory institutions.

All the countries of sub-Saharan Africa should aim to enhance their capacity for research and development, transfer of technology, and commercialization of significant research findings. This would require partnerships between private, public and academic leadership of respective countries to examine what has worked elsewhere and why, what has been tried that failed, and how to adapt these experiences to their own settings.

5.3.4 Strengthening National Academies

Only a few of the countries of sub-Saharan Africa have functioning academies of science. These honorific organizations play an important role in showcasing the best of the academic community, and in providing appropriate reward and recognition for outstanding performers. They also help to shape the culture and tradition of intellectual communities, placing appropriate values upon merit and performance. It is recommended that national university systems lead a new effort to rally external support, particularly from foundations, to strengthen national academies where they already exist, or otherwise to catalyze the founding of new ones.

5.3.5 Arranging Technology Missions

A useful modality for building capacity around critical issues is to mount technology missions. A mission would arise from a deliberate decision by stakeholders to define a social objective that requires a major technological input, and then to mobilize all necessary resources for achieving that objective within a specified time frame. Such a mission should seek specific collaboration that links all stakeholders and leverages other resources. Priority areas which might present mission opportunities include:

- renewable energy research
- food production and security
- environmental sanitation and water resources
- telecommunication, electronics and information technology

5.3.6 Promoting Scientific Production

Africa's scholarly community needs to substantially increase its contribution to the global pool of knowledge. A significant amount of on-going research as well as indigenous knowledge remains either unpublished or poorly documented. The current global knowledge revolution powered by new information technologies provides an unprecedented opportunity for reducing the isolation of African scholars, and for expanding the knowledge resources of the continent.

National research institutions should increase intensity and coverage of their research programmes. They should conduct critical studies that lead to the determination of priorities for strategic research. They should also identify those research areas that are most likely to benefit society within a short period of time, and reposition themselves to address the priority needs of their countries. African institutions need to carefully seek out and utilize emerging opportunities for this purpose.

Reform of the university system in sub-Saharan Africa is a necessary step to enhance research environment. Such reform would include cultivating linkages with the private sector and encouraging collaboration with non-university research and development. The institutions should also improve the reward system to compensate scientific production and technological innovation. Increased contribution of African science to the global intellectual knowledge base would greatly boost the morale and enthusiasm of African scholars whose relative isolation tends to diminish the appreciation of their scholarship.

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