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State of Science and Technological Capacity in Sub-Saharan Africa

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Abbreviations & Acronyms

AAU	Addis Ababa University
ACTS	African Centre for Technology Studies
AMREF	African Medical Research Foundation
ATPS	African Technology Policy Studies
CIRAD	International Cooperation Centre for Agricultural Research and Development
ESTC	Ethiopian Science and Technology Commission
EU	European Union
FAO	Food and Agriculture Organization
IAEA	Iernational Atomic Energy Agency
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
ILCA	International Livestock Centre in Africa
ILRI	International Livestock Research Institute
INRAN	Natural Research Institute of Niger
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
KEMRI	Kenya Medical Research Institute
KETRI	Kenya Trypanasomiasis Research Institute
KPLC	Kenya Power and Lighting Company
MNCs	Multinational Corporations
MSIRI	Mauritius Sugar Industry Research Institute
NAPRI	National Animal Production and Research Institute
NASCOP	National Aids Control Programme
ORSTOM	French Institute of Scientific Research for Development Cooperation
SSA	Sub-Saharan Africa
STDs	Sexually Transmitted Diseases
S&T	Science and Technology
R&D	Research and Development
UON	University of Nairobi
UNESCO	United Nations Educational Scientific and Cultural Organization

USAID	United States Agency for International Development
WARDA	West Africa Research Development Association
WHO	World Health Organization

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Chapter One

Introduction

Governments in Sub-Saharan Africa (SSA) have emphasized the overwhelming significance of scientific and technological change in the development process. In numerous policy documents, nation-states have expressed their desire to promote scientific and technological development in a bid to accelerate economic change and enhance the well being of their citizens. Such emphasis has also been reiterated in regional and continental meetings attended variously by heads of state, academics, researchers and professionals. The most significant meetings were the CASTAFRICA I (Dakar, 1974) and CASTAFRICA II (Arusha, 1987). The United Nations Conference on Science and Technology held in Vienna in 1979 was also instrumental in raising awareness among Africans on the significance of science and technology (S&T). Inspiration on this score has also emanated from the Lagos Plan of Action (1980). The plan exhorted African countries to integrate scientific and technological imperatives in their development endeavors. The potential value of this critical ingredient has in the main assumed a profound degree of immediacy, and has, in consequence, reverberated across SSA with palpable resonance ever since. This can be attested by national efforts to create science and technology institutions in Africa.

Stemming from this recognition and fundamental developmental aspiration, SSA countries embarked on a series of new S&T initiatives, while correspondingly buttressing the research and development programmes that had been in the continent. These efforts are varied both in extent, scope and emphasis across SSA countries. However, while the S&T landscape has been marked by notable differences, it is also characterized by shared commonalties. Out of this dichotomy in Africa's S&T research capacities have emanated numerous success stories as well as cases of failure, both of which in their own respective ways, offer vital lessons of experience and policy concern. These will become evident as the study sifts through the maze of strengths, weaknesses and constraints, that have impacted on the evolution of these S&T capacities.

Chapter Two

General Overview

The development of science and technological capacities in SSA has occurred in both private and public agencies whose activities have often remained uncoordinated[1]. This tendency has often led to resource misuse and duplication. More fundamentally, it has compromised efforts at spearheading the technological drive in a bid to evolve S&T capacities within states. The truth is that this has evidently limited the usefulness of existing mechanisms for S&T development in SSA countries.

Between the mid-1980s and 1990s, Africa's share of world's scientific output fell from 0.5 to 0.3 %. African scientists number about 20,000 (researchers and technicians).

This is roughly less than 0.36 % of the world's total. Moreover, research and development (R&D) activities have registered a notable decline over the years with highly skilled and trained nationals migrating to the developed countries[2]. Figures indicate that R&D approximate on average only 0.2 % of gross national product of African countries. R&D institutions have generally fallen under five broad categories:

(1) government research institutes,
(2) corporate research institutes in parastatals and other public utilities,
(3) higher education research in universities and colleges of S&T,
(4) private sector research in companies, and
(5) international research centres.

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1 See Table 6 in this text for examples of duplication across SSA countries. Also, because of the huge financial and infrastructural requirements involved, no NGOs are involved in research and development work. However, several NGOs are presently engaged in S&T
issues at the level of policy research. Examples include African Centre for Technology Studies (ACTS), Nairobi and African Technology Policy Studies Network (ATPS), Nairobi.

2 See Seithi, M. (2000) "Return and Reintegration of Qualified African Nationals". Paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa, Addis Ababa, Ethiopia, p.2.

However, the collection, compilation and classification of vital science and technology statistics lags far behind in SSA. In this respect, the determination of the status of S&T capacities has depended on information and reports that have generally offered an incomplete picture of the true state of affairs. This report provides the status of some of the most crucial measurement activities, which SSA has yet to introduce and systematize for comprehensive use in the years ahead.

Chapter Three

Profile of Science and Technological Capacities in SSA

Africa's budgetary contribution to research and development (R&D) activities as a percentage of growth domestic product (GDP) has been extremely low. Funds allocated for research have comparatively been higher than flows earmarked for development and commercialization. Moreover, financial resources have shown a marked bias in support of agricultural research with livestock and health domains receiving relatively smaller amounts, respectively. Finally, institutions undertaking industrial research e.g. in energy and environmental fields, are relatively fewer in number compared to those involved in agricultural research. Funding proportions have generally reflected this skewed dichotomy[3].

Political commitment to S&T in SSA

Governments in SSA have expressed political commitments in support of S&T for development. However, the relative strengths have differed between countries. Most SSA countries have long established national councils of S&T and ministries to address the issue. The United Nations Educational, Scientific and Cultural Organization (UNESCO) assisted several countries in establishing national S&T institutions. Their mandates, however, have been long on generalities and short on specifics. Evidence has revealed that, on the whole, the S&T policy institutions have not been instrumentally effective in actively informing and guiding scientific and technological change. Levels of commitment to S&T for development in SSA are varied and expressed in different forms. Frequently, public statements have been made indicating awareness of the importance of S&T in national development.

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3 See the budget allocations for coffee, tea and pyrethrum research institutions in Kenya. These are largely export-oriented. However, the Kenya Agricultural Research Institute is heavily biased towards food crops. It is also important to bear in mind that international research institutions such as International Centre of Insect Physiology and Ecology (ICIPE) and International Livestock Research Institute (ILRI) have two types of funding, restricted and unrestricted. However, it would be vital to carry out a study on the distribution and skewness of funding, since no research has been undertaken to put the whole issue in context.

In fact, it is common to find official statements of national S&T policy reflected in the first development plans or early sessional papers on policy.
It is also often the case to see legislation on S&T policy matters enacted, for instance, in areas of intellectual property. However, most SSA countries have not integrated S&T provisions in their respective constitutions.

Status of S&T indicators in SSA

Determining the configuration of science and technological capacities (in terms of type, level, quality and quantity) in SSA would have been a straightforward task, if comprehensive national frameworks of S&T indicators and measures were in place and operational. A cursory appraisal of the SSA landscape has revealed that most countries have relied on a sparse set of measures, which offer an incomplete picture of existing S&T capacities. Government departments in charge of collecting, compiling, and classifying national statistical information, have not identified the most basic indicators, let alone prepared formats for their institutionalization. In fact, data for most S&T indicators are neither gathered nor compiled. As such, they have not been reflected in the most consulted statistical documents produced by national data agencies.

The lack of aggregation could be attributed to the general absence of policy requiring public and private institutions, to submit data annually to national data agencies and to do so within a given format. However, some data is still collected and made available to international institutions such as the World Bank, UNESCO, and United Nations Development Programme (UNDP). Data for this report rely heavily on published material from these sources.

At the outset, it is worth mentioning that the assessment of scientific and technological capacities in SSA is awfully difficult, because no indigenous national capabilities exist to monitor trends in performance at different levels as shown in Table 1.

Table 1: Levels and status of science and technology measurement activities in Sub-Saharan Africa

Level	Scope and Purposes	Status
Firm Level of analysis	Collection and Publication of Key indicators for internal monitoring, budgeting and planning	Most public corporate, private and locally based international research agencies have carried out the measurement activities, though public national research have not regulazied the process on a year to year basis
Inter-firm comparisons	Inter-firm comparisons to reflect specific measurements on the basis of projects undertaken	Has never been carried out for firms in SSA
Industry & national level analysis	- Industry and national level statistical surveys for use by government, private agencies and other potential end-users (UN agencies, NGOs, etc.) - Requires use of standardized definitions. - Can point to important conclusions for national S&T policy making	- Has never been carried out for industries in SSA - Not yet carried out in SSA - Not yet derived for SSA.
Regional and International comparisons	- To be carried out by regional and international agencies. - Requires harmonization of various national definitions and procedures - Useful if activities are innovative and catalytic, leading to dissemination of best practice across national frontiers.	- Process not yet initiated. - Process not yet initiated. - Process not yet initiated.

Source: Khalil, M.H., 1999.

Moreover, measuring the progress and status of S&T has been constrained by the lack of suitable indicators. SSA countries are therefore relatively indisposed, given the poor identification and delineation of S&T measurement activities.

It is also worth noting that SSA countries have had no tradition of grouping the S&T measures in terms of input and output indicators, even when this information appears in general classification formats. The absence of a systematic framework of data collection and formatting has made it difficult for multi-level comparisons to be made. This broad failure to devise systematic measurement and classification of S&T activities has revealed several deficiencies in SSA S&T information system. Clearly, the absence of such indicators has compromised the development of S&T capacities in Africa in a number of ways. The weaknesses include:

- The non-incorporation of S&T indicators in the socio-economic planning process.
- Inability to develop an integrated planning framework.
- Difficulties of influencing practice and policy.
- Poor understanding of the factors influencing S&T development.
- Inability to undertake suitable comparison and therefore, the inability to focus on critical issues worthy of attention by national planners.
- Failure to comprehend the consequences of planned S&T activities.

In addition, the gaps and/or lacunae of a systematic classification system has militated against comprehensive evaluation of:

- level and quality of scientific and technical information;
- national capabilities with respect to the management of R&D commercialization of research results, and reverse engineering services; and
- science and technology gaps and the levels of production in national economies[4].

It is essential to point out that data for the construction of the earlier mentioned indicators, is potentially available in most R&D institutions, though the information is either scattered in various reports or has yet to be compiled, standardized and systematized. Most universities in SSA for example, can ask various departments and faculties to compile information on S&T papers published, or can tabulate qualification profiles of faculty members by field of specialization. Similarly, R&D institutions can provide systematized and standardized information on sources of R&D funds, current and capital expenditures on R&D by field of specialization, and stock of S&T personnel by field of specialization. A standardized questionnaire seeking information on a comprehensive set of S&T indicators, circulated to national R&D institutions, and prepared by and returned to a central statistical office, would be a major step in institutionalizing S&T indicators at national and regional levels.

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4 Technology gaps would include technical, information, institutional, and human resource evaluations.

Chapter Four

Education, Research and Development

At present, profiles of education in SSA are inadequately captured and represented by a limited set of indicators discussed later. What becomes evident is that the tertiary level figures tell us little about the comparative distribution of students according to, say, the field of specialization in some detail. It would have been a lot more useful if the breakdown reflected the following categories: engineering sciences, earth sciences, physical sciences, biological sciences,mathematics and computers, agricultural sciences, medical sciences, and social sciences. These vital statistics are available at the institutional level, but no attempt has been made to systematize them at the national level.

Clearly, the generic aggregation of such data has tended to limit their usefulness for policy purposes with respect to S&T development. A closer look at Table 2 shows that the data for primary, secondary and tertiary education for different countries are available for different years, thus making the art of comparison almost impossible.

With respect to S&T indicators (both output and input), it is crucial to note that data for basic research, applied research, development of innovations, and production activities (such as stock of S&T personnel), are available, but not collected and systematized. National level information for input indicators (such as primary, secondary and tertiary level education) is collected and systematized, but rarely reflected in detailed and comprehensive categories. However, for output indicators, information is not registered and has yet to be collected and reflected in national statistical documents.

Table 2: Student population in selected African countries

Country	Year	Primary Education: pupils enrolled	Secondary Education: pupils enrolled	Tertiary Education: pupils enrolled
Angola	1991/2	989443	218987	6331
Benin	1996/7	779329	146135	14055 (1996)
Botswana	1996	318629	109843	8850 (1996/7)
Burkina Faso	1995/6	700995	116033 (1994/5)	8911 (1996/7)
Burundi	1995/6	518144	47639 (1994/5)	1123 (1992/3)
Cameroon	1996/7	1921186	459068 (1994/5)	33117(1990/1)
Chad	1996/7	680909	99789	3446 (1996/7)
DRC	1994/5	5417506	1514323	93266
Ethiopia	1996/7	4007694	889650	42226
Gabon	1995/6	250693	80552	4655 (1994/5)
Ghana	1994/5	2154646	841722	9609 (1990-2)
Kenya	1995	5544998	632388	35421 (1990/1)
Nigeria	1994	16190947	4451329 (1993/4)	207982
Uganda	1995	2912473	256258	34773 (1996/7)
South Africa	1995	815930	3749449	617897 (1994)
Sudan	1996/7	3000048	405583	59824 (1990/1)
Zimbabwe	1998	2507098	847297	46673 (1996)
Senegal	1997/8	1026570	215988 (1997/8)	24081 (1994/5)
Tanzania	1997	4057965	234743 (1997)	17812 (1997/7)

Source: UNESCO (1999) Statistical Yearbook, 1999.

A better presentation is reflected in Table 3 where there are some science literacy indicators; South Africa and Zimbabwe are leading the continent in adult literacy and primary school enrolment. Other countries with high primary enrolment ratios include Namibia, Botswana, Lesotho, Togo and Malawi, to mention a few. South Africa also leads in secondary enrolment with countries like

Namibia, Botswana, Lesotho, Congo and Malawi, also registering high proportions. In general, the rates of enrolment decline at tertiary levels of education.

Taking the total number of personnel involved in research and development work in Africa, it is revealing that the vast majority belong to the category of auxiliary staff. The actual researchers make up only 15 % of the general R&D workforce. This is summarized in Annexes 1-3.

As observed in an earlier section, research centres in SSA are generally public outfits that were established to fulfil a set of objectives arising from well-defined needs (Annex 4). Unfortunately, funding limitations have constrained the capacity of these public research centres from moving to the development and commercialization stages. The main area of research has been agriculture. The relative strengths of the various specializations appear in Figure 1.

Research in industrial-related activities is limited. In fact, the absence of strong linkages with the wider sphere of economic production, partly explains why resources are not heavily invested in industry, compared to agriculture.

Yet, it should be pointed out that the tradition of agricultural research in most SSA countries traces its roots to the colonial period. Ever since, the orientation of research activities has largely been commodity-specific.

South Africa has the largest number of research institutions (172) in SSA (see Annex 5). Countries like Ethiopia, Tanzania, Zimbabwe, Nigeria, and Kenya have several, most of which are agricultural in orientation. Annex 5 summarizes the distribution of research centres across fields of specialization. Annex 6 shows the distribution of R&D personnel in selected SSA countries. Again, South Africa leads (Annexes 5 and 6) in the number of researchers.

Table 3: Science enrolment, R&D personnel and industry in Sub-Saharan Africa

Country	Net Enrolment Ratio				
	Adult Literacy Rate(%) 1997	Primary (as % of relevant age group) 1997	Secondary (as % of relevant age group) 1997	Tertiary Science(as % of total tertiary) 1995	R&D Scientists and Technicians per 1000 people 1990/96
South Africa	84.0	99.9	94.9	57	1.2
Tunisia	67.0	99.9	74.3	24	0.4
Algeria	60.3	96.0	68.5	52	-
Namibia	79.8	91.4	80.7	5	-
Egypt	52.7	95.2	75.1	15	0.7
Botswana	74.4	80.1	88.8	24	-
Gabon	66.2	-	-	-	0.2
Moroco	45.9	76.6	37.7	29	-
Lesotho	82.3	68.6	72.9	25	-
Zimbabwe	90.9	93.1	59.1	23	-
Eq. Guinea	79.9	79.3	68.5	-	-
Ghana	66.4	43.4	-	-	-
Cameroon	71.7	61.7	39.8	-	-
Congo	76.9	78.3	84.1	11	-
Kenya	79.3	65.0	61.1	-	-
Sudan	53.3	-	-	-	-
Togo	53.2	82.3	58.3	16	-
Nigeria	59.5	-	-	41	0.1
Zambia	75.1	72.4	42.2	-	-
Senegal	34.6	59.5	19.9	-	-
Cote d'Ivoire	42.6	58.3	34.1	26	-
Benin	33.9	67.6	28.2	19	0.2
Tanzania	71.6	47.4	-	39	-
Djibouti	48.3	31.9	19.6	-	-
Uganda	64.0	-	-	13	-
Malawi	57.7	98.5	72.6	18	-
Angola	-	34.7	31.2	-	-
Guinea	37.9	45.6	14.6	-	-
Chad	50.3	47.9	17.9	14	-
Gambia	33.1	65.9	33.3	-	-
Rwanda	63.0	78.3	-	-	-
CA Republic	42.4	46.2	19.0	-	0.1
Mali	35.5	38.1	17.9	-	-
Eritrea	-	29.3	37.9	-	-
Guinea Bisau	33.6	52.3	24.1	-	-
Mozambique	40.5	39.6	22.4	50	-
Burundi	44.6	35.6	17.1	-	0.1
Burkina Faso	20.7	32.3	12.8	18	-
Ethiopia	35.4	35.2	24.8	36	-
Niger	14.3	24.4	9.4	-	-
Sierra Leone	34.3	44.0	-	30	-

Source: Human Development Report (UNDP) 1999.

Figure 1: Fields of specialization for R&D centres in SSA.

Chapter Five

Scientific and Technological Research Priorities, Diversity and Distribution

In general, scientific and technological research in SSA has demonstrated a pronounced bias towards agriculture. This sectoral tendency is, however, not monolithic. The bias is also characterized by a narrow diversity of specializations, that are inclining more towards food crops. Food crops have dominated the research agendas, but sizeable budgets have also been devoted to cash crops. This is particularly true in the case of coffee, tea, pyrethrum and cocoa. Funding has thus showed a skewed distribution in favour of cash crops. In addition, SSA capacities have not only reflected this propensity, but have also entrenched the long-established lines of research. It is to these issues that I now turn. It is not clear what criteria has been used to pursue research, but preliminary evidence suggests that food security and foreign exchange concerns have been key factors in the selection of research lines.

Established domains in S&T research

There is significant R&D capacity in SSA, though one must hasten to add that the concentrations are inadequate. This capacity exists mainly in public institutions such as universities and government owned research institutes (Table 4). In Kenya, for example, significant R& D capacity exists in the University of Nairobi (UON) as well as Moi, Egerton, Jomo Kenyatta University of Agriculture and Technology (JKUAT), and Kenyatta universities. There is also substantial R&D capacity in Kenya Agricultural Research Institute (KARI) facilities, which deal mainly with research on crops and livestock in addition to crop-specific research on coffee, tea and sugar. Apart from this capacity held in public institutions, SSA countries have also significant installed R&D capacity in institutions and facilities owned and funded by international NGOs and other international development agencies. Considerable capacity happens to exist in international agricultural research centres. Examples in Kenya include research facilities by ICIPE, ILRI, International Centre for Research in Agroforestry (ICRAF) and African Medical Research Foundation (AMREF). There is also smaller scale localized research capacity in many countries. Most of these obtain their funding from external sources. The donors include: Australia, Austria, Belgium, Germany, European Union, Japan, Netherlands, Switzerland, United Kingdom and Norway. International organizations such as United States Agency for International Development (USAID), World Health Organization (WHO), the World Bank, and International Development Research Centre (IDRC).

Not much R& D capacity in SSA is under private commercial institutions with the notable exception of multinational corporations (MNCs) operating in Africa. These commercial concerns are mostly in the production of such export commodities as coffee, tea, cocoa, pineapples and minerals, such as copper and iron ore. The MNCs have been involved in these domains over a long time and have developed R&D activities centred mainly on improving the production processes, product quality and the marketing of improved output. Such R&D is therefore commercially oriented and profit driven.

Their main objective is to enhance the profitability of these enterprises and not necessarily to address the R& D and development agenda of the countries in which they operate. In East Africa, for example, companies like Brooke Bond have played an important role on the R & D effort directed at coffee and tea, and Del Monte in Kenya carries out research on pineapple production.

Areas in the fields of Agriculture and biotechnology have been selected and established in different countries in SSA (Table 5). With respect to biotechnology, the commercialization of products derived from research has been one of the weak points in SSA. Many research institutions have yet to deepen their knowledge in this area.

Table 4a: Agriculture Sector: Established domains of R&D capacities in Africa

Country	Field of Research	Institution
Ethiopia	- Production of higher yield varieties and development of sustainable farming systems. - Development of gene bank involving farmers at several stages for use in crop. - Use of culture technology to propagate forest species including cofee	Ethiopian S&T Commission Institute of Agriculture Research, International Livestock Centre in Africa (ILCA), Plant Generic Resources
Kenya	- Maize, tea, pyrethrum, coffee fruits, horticultural crops - Development of *in vitro* tissue culture techniques - Development of diagnostic tests for viruses bacteria, pathogeric fungi, insect pests - Idenfication of disease and pest resistant plants - Identification of ITK useful to farmers - Biological Control of diseases and parasite insects	KARI, Kenya Forestry Research Institute (KEFRI), International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), UON, JKUAT
Uganda	- Research on Production of higher yeild varieties for beans, other legume species, soya beans, groundnuts	KARS, (Nyunda), Makerere University
Senegal	- Forestry (*In vitro* identification of symbolic associations of vaneur tree species). This could be used in reforestration schemes. - Biofertilizer studies on higher nitrogen fixing Azolla strains for use in paddy fields - Forestry	Senegalese Institute for Agricultural Research, ORSTOM
Mali	- Paddy development through fertilizer studies on eight Azolla strains	West Africa Rice Development Association (WARDA)
Niger	- Biological nitrogen fixation through cowpea inoculation tools under FAO regional project	National Research Institute of Niger (INRAN)
Cote d'Ivoire	- Channel propagation of oil palm to replace the Cocoa miracle that had considerably stumped - Improve on techniques of old palm improvement and propagation - Development of better techniques in both cultivation and processing of rubber - Other areas were soya beans and cowpea, ornamental horticulture	French Insitute of Scientific Development Cooperation (ORSTOM), International Research for Cooperation, Centre for Agricultural Research and Development (CIRAD) ORSTOM
Ghana	- Cocoa improvement through elimination of viral and bacterial diseases	Faculty of Agriculture, University of Ghana
Nigeria	- Agricultural improvement of maize, millet, sorghum	ICRISAT
Gabon	- Focuses on propagations of food and fruit crops - *In vitro* micro-propagation	Centre for the introduction adaptation and propagation of plant material
Zimbabwe	- Manufacture of Polythene trays	Brookfield seedlings, Wattle company, Glenburn seedling company
Mauritius	- Sugar-cane cultivars	Mauritius Sugar Industry Research Institute (MSIRI)
Tanzania	- Dodoma wine company - Endangered forest species project, uses tissue culture techniques for mass production of these forest species	University of Dar -es-Salaam, Tanzania Commission of S&T
Burundi	- *In vitro* micropropagation for rice, maize and sorghum - Potato and banana improvement	Agricultural and Zoo Technical Institute (IRAZ)
Rwanda	- Increasing productivity of food legumes	Rwanda Institute of Agriculture and Science
Zambia	- Soya beans project - led to inclusion of other legume inocurants	Mt. Mukuler Research Station

Source: Own Survey, 2000.

Table 4b: Livestock Sector: Established domains of R&D capacities in Africa

Country	Field of Research	Instituttion
Nigeria	- Breeding trypanasomiasis resistant cattle -Development of new breeds of cattle for beef and milk production	National Livestock Research Institute, National Animal Productiona dn Research Unit (NAPRI)
Ethiopia	- Development of diagnostic kits and nuclear and probes to identify leprosy, *leshmamasis* and *trypanosomiasis* antigerms	ILCA
Kenya	- Improvement of disease diagnostic techniques and vaccine development	National Veterinary Research Centre, UON, KARI, KETRI
Uganda	- Livestock improvement programmes	ILRI, Makerere University, Kawanda Agricultural Research Station

Table 4c: Health Sector: Established domains of R&D capacities in Africa

Country	Field of Research	Institution
Nigeria	- Screen natural resources that can be used for pharmaceuticals and drugs development as well as production of vacancies	Institute for Medical Research University of Ibadan
Gabon	- Improve on all aspects of human fetility - carry out biological as well as behavioral studies at the primate centre. Also focussed on STDs - four was more of public health than research. however, effect of parasitic diseases on human reproduction remunerated subject of origan research	International Centre for Research Franceville (CIRMF), Regional Centre for Research and Training in Human Reproduction.
Kenya	- Development of diagnostic techniques focussing on malaria, schistosomiasis, leshmaniasis, hepatitis B, diabetes, hypertension, Aids, sleeping sickness	KEMRI, UON, NASCOP, KETRI
Uganda	- Research into control of sleeping sickness	ILRI

Table 4d: Energy Sector: Established domains of R&D capacities in Africa

Country	Field of Research	Institution
Ethiopia	Research cooperation areas: - Assessment of energy supply demand and current pattern of consumption - Training and development of manpower - Building of research and demonstration centres Post harvest technology high costs of imported diesel	Ethiopia Energy Committees The S&Y Commission, Rural Technology Department of MOA
Kenya	- Woodfuel energy - Hydropower energy - Power alcohol production - Solar energy Wind power utilization - Biogas utilization	University of Nairobi, Kenyatta University, Ministry of Agriculture, Ministry of Energy, Electricity Regulartory Board
Nigeria	- Ecowas Energy Survival Project - Ajaokula steel plant	Individual energy exports, Nigerian University, Energy Commission of Nigeria
Tanzania	- Arusha appropriate technology project - absorbed into the Centre for Agricultural Machinery and Rural Technology	Tanzania National Research Council (UTAFITI)
Zambia	- African energy programmes - Charcoal utilization project - Solar and wind energy programme	Department of Mechanical Engineering, University of Zambia
Nigeria	- Coal industry	Nigeria Coal Company
Sierra Leone	- Technological capability acquisition for oil refining	Sierra Leone Petroleum Mining Company

Table 5: Selected established areas in the field of agriculture and biotechnology

Field of Specialization	Countries
Banana	Burundi, Cameroon, Egypt, Gabon, Ghana, Morocco, Nigeria, Senegal, Tunisia
Plantain	Cameroon, Gabon, Ghana, Nigeria
Tuber plants	Algeria, Burundi, Egypt, Kenya, Mauritius, Morocco, Tunisa, Zimbabwe
Cassava	Burundi, Cameroon, Congo, Gabon, Nigeria, Zimbabwe
Taro	Cameroon, Cote d'Ivoire, Gabon, Ghana
Yams	Cameroon, Cote d'Ivoire, Gabon, Ghana, Nigeria
Sweet potato	Burundi, Kenya, Zimbabwe
Rice	Senegal
Soybeans	Zimbabwe
Maize	Zimbabwe
Groundnut	Zimbabwe
Tea	Kenya, Uganda
Cocoa	Ghana, Ivory Coast
Coffee	Kenya, Uganda
Palm oil	Ghana, Nigeria

This could be one reason why commercialization has been weak. The other relates to the tendency for research institutions to focus more on research and very little on development. But more importantly, institutions have experienced the following drawbacks:

- Unrealistic expectations from biotechnologies — this has stemmed from the perception that biotechnology would offer magic solutions to the research problems.
- Low support for research and development.
- Diminished income from expectations.
- Unfavourable tax structures — farmers' incomes derived fromcommercialized products have not been exempted from taxation, or at least the machinery they use in order to encourage them to use the biotech innovations.

- Low probability of raising capital.
- Weak prospects for successful commercialization of biotechnology-derived products.

There is considerable installed R&D capacity in SSA[5], but this capacity is grossly inadequate considering the development needs of the region, and yet even the capacity that exists is seriously under-utilized. The SSA region contains the majority of the poorest people on earth. These populations face acute problems and challenges arising from the very conditions of their poverty. The region is currently being ravaged by HIV/Aids in which over one third of the population in most countries are affected, millions are dying every year, while others are rendered unproductive and destitute by the pandemic. The region also, is ravaged by hunger and starvation caused by inability to deal with adverse weather conditions such as the floods that devastated Mozambique early in 2000 and the severe drought threatening the lives of millions in the Horn of Africa (affecting Kenya, Ethiopia and Eritrea). SSA has huge proportions of the people wallowing in abject poverty and destitution yet the paradox is that the region is tremendously rich in natural resources such as gold, diamonds, iron ore, copper, crude oil and other minerals, such as precious stones as well as large swathes of equatorial forests, mountain forests, wildlife, mighty rivers and lakes and plenty of sunshine all the year round.

Apart from the inadequacy of the available R& D capacity in SSA, it is paradoxical that even that capacity which is available, is grossly under-utilized. There are two main reasons for this state of affairs:

(a) Low incomes

Since most people in SSA are poor, the governments raise low pay to researchers, so that most of them do not stay long under government employment, but live in search of greener pastures elsewhere. Several institutions contacted in Kenya cite this factor to be the main reason for migration[6]. The governments also cannot afford the requisite equipment and materials that are required for research. As a result of all this, many research facilities have significant excess capacity.

5 This refers to the existing infrastructural, technical and human facilities.

6 But to appropriate the significance of this factor Africa-wide, a separate study needs to be conducted. So far, no such attempt has been on the cards.

(b) Inadequate appreciation of R&D

Many societies in SSA and their governments do not have a good appreciation of the value of R&D. As a result, instead of increasing the R&D efforts to solve their pressing problems, they reduce such efforts, particularly when economic conditions are not good[7]. Thus, it is noted that as the economic performance of most SSA countries deteriorated in the 1980s and 1990s, public research institutions including public universities have increasingly been starved of funds so that they could not play their rightful role in helping solve the problems these societies face. The little R&D activities that have continued in these public institutions, have been mainly a result of funding from external sources[8], such as Rockefeller Foundation, the Ford Foundation, the Friedrick Ebert Foundation, Japanese International Cooperation Agency (JICA), USAID, Swedish International Development Agency (SIDA) and Canadian International Development Agency (CIDA).

Nature of the R& D Capacities

The R & D capacities in SSA exist in the following forms:

Capacity in university and other institutions of higher education

Most public universities and institutions of higher education in SSA have established S&T capacities. However, this capacity tends to be more on the pursuit of research and pure science, mainly for academic reasons. The research is often intended to provide material for publication in academic journals by faculty members and to satisfy degree requirements by the students. Often, such research has little or no bearing to the technology and development needs of the country. This partly explains why these institutions have contributed little to the generation of new ideas, processes and technology in SSA regions[9].

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[7] The need for a new model is invaluable here. The new paradigm should at least entail extra resources that would focus on commercialization and development.

[8] No work has been done to comprehensively capture the allocation and distribution of funding in SSA research institutions. It is possible to pursue this effort on national and regional scales.

[9] It is important to carry out a needs assessment and to steer the efforts of researchers towards addressing societal problems.

Capacities established by private corporations

As already noted, much of the production and marketing of export commodities in SSA is done either directly or indirectly by private corporations. Since the beginning of colonialism, many of these corporations have engaged in research and development activities geared mainly to maximize their profit. Such R&D capacities have tended to improve the way they are processed and stored, the manner of transportation and handling, and the way they are marketed world-wide. Research of this kind is therefore not meant to meet the R&D needs of the society. As a result, commodities that these companies are not interested in tend to be neglected even when they hold much domestic potential. Private corporations, for example, undertake and fund considerable research in East Africa on crops such as tea and coffee, but hardly any research on important food crops such as millet, sorghum, cassava and cowpeas. Only public research institutions exert efforts in these areas though the Kenya Coffee Research Foundation (KCRF) and others on tea do tackle research in these respective fields[10].

R & D capacities supported by foreign agencies and institutions

Agencies such as International NGOs (e.g. ICRAF, ICIPE and ILRI), international philanthropic agencies (e.g. Ford Foundation, The Carnegie and Rockefeller Foundation), foreign aid agencies (e.g. USAID, JICA and FINNIDA) and UN bodies, support considerable amount of research and development activities in SSA. Dutch research tends to be driven by social needs and therefore tends to fill in the gap in R&D, which is left by public institutions and agencies. The research funded can be academic or even oriented towards profit, but in most cases, its principle objective is to help these societies acquire the scientific knowledge and technology, to mobilize their resources for faster development.

Corporate initiatives

It has already been noted that private corporations tend to fund commodity - specific research and development. Such research has resulted in considerable improvement in the way these commodities are produced, processed, transported and marketed. This has given rise to thriving industries and sectors such as pineapple production and processing by Delmonte in Thika, Kenya, flower reproduction by Sumac, and improvements in coffee and tea in east and central Africa.

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10 Presently. no research effort is being directed towards compiling information on funding levels between crops. An Africa-wide study could reveal important policy issues in this regard.

Most corporations operating in SSA use technologies that are already patented in their mother countries. This is particularly the case in industrial processing, packaging and transportation. Since such technology was developed to suit the conditions in the developed countries, they tend to be inappropriate within the context of the conditions obtaining in SSA societies. When technology is inappropriate in a particular context, it tends to involve higher opportunity costs for the society, leading to resource misallocation. Many multinational corporations involved in such industrial activities as processing and assembling of products, tend to use capital intensive techniques of production. This distorts resource use patterns, considering the configuration of natural resource endowments in African countries.

Public Initiatives

Despite the lack of proper funding and enthusiasm on the part of African governments, public institutions continue to play an important role in maintaining R & D activities in SSA. There have been a number of spectacular achievements coming form these institutions, although the disseminating of the products and processes arising thereof, has been very weak. In Kenya, the UON has made significant contributions to the production of new varieties of pigeon peas (see Box 1).

Success has also been realized in legume research on food crops. Recently, JKUAT made a spectacular breakthrough in the breeding of new banana varieties through tissue culture. These varieties are revolutionizing banana production in Kenya (see Box 2).

Box 1 A Success story with a twist in the tail: the case of pigeon pea improvement

Pigeon peas constitute an important source of plant protein for humans, especially in the dry areas of SSA. They are legumes and fix atmospheric oxygen through nodules in their roots. The problem in Kenya was that the varieties grown took one year (two seasons) to reach maturity in the dry Ukambani plains. These varieties are sown during the short rains from November to December. They grow slowly through the short, but intensely hot season from January to March, reaching maturity during the long rains from March to June. They flower during the long rains and are harvested in July or August. Due to the uncertainty of rainfall in arid and semi-arid Africa, these varieties do not reach proper maturity, and give good yields when rains in one of the seasons were inadequate. Researchers at the Faculty of Agriculture in the University of Nairobi produced a new variety, which had the following durable characteristics:

(a) grew and matured in one season or about four months,
(b) was shorter than the taller varieties and therefore easier to manage (about 1 metre height),
(c) was very high yielding,
(d) continued to produce as long as it was watered, and
(e) was highly palatable, especially when used as a vegetable in its green stage.

When the University of Nairobi showed this to farmers in demonstration plots, especially during agricultural shows, farmers received it with much enthusiasm and excitement. Propagation of this variety began and was made available through commercial seed agencies.

Currently, farmers are frustrated because they cannot get the seeds for this variety. Public institutions which were supposed to produce them have failed, mainly because they are not profit seeking institutions, but are more interested in academic research.

Box 2 Success story: the case of banana

Banana is an important food crop in Kenya, especially in the well-watered regions of Central, Rift Valley, Western, and Nyanza Provinces. In these regions, banana is eaten when ripe or cooked in the form of plantains 'Matoke'. Banana varieties in many parts of Kenya have very tall stems and take very long to mature (often over 18 months). A JKUAT researcher noted that yields per plant were disappointing and propagation was very slow and tideous, since people normally used suckers as a means of propagation. She undertook research to change all these. She was successful beyond measure. She was able to introduce in the country banana production through tissue culture, in which clones could be produced from chosen high yielding plants. Thousands of such clones could be produced from a few plant tissues. The result was a short banana variety (Dwarf Cavendish type), reaching an average height of one and a half metre. This variety matures in 12-14 months, hence reducing the time to maturity by about 50%. It also produces a bigger bunch with more hands and fingers, which mature quickly, giving highly palatable bananas when ripe. When this variety was shown in agricultural shows, it caused quite a stir among farmers. Many immediately booked the suckers intending to convert their bananas exclusively to this variety. Indeed the demand was so brisk that it could not be satisfied.

This has been the case to date and indicates that farmers potentially respond positively to technologies that increase their yields and profits. This research is being expanded to include other varieties of bananas and other crops, and provides a good illustration of the fact that when it is well targeted, R&D can have desirable effects on the livelihoods of many in SSA.

Source: Own Survey, 2000.

Chapter Six

Strengths and Weaknesses of S&T Capacities (non-Industrial) in SSA

One of the principal causes of the weaknesses of S&T capacity in SSA is the socio-economic and political setting (or conditions) obtaining in most of these countries (see Box 3). The main aspects of these conditions are:

(a) lack of good leadership;
(b) abject poverty on a massive scale; and
(c) a general populace, which does not fully appreciate the value of the S&T available to them.

Leadership

One of the factors that handicap the development process in SSA is the general lack of good political leadership so pervasive in the region.

Countries like Mauritius have demonstrated that with a clear and distinct policy on S&T and economic development, it is possible to transform a poor agrarian society as obtains in most SSA countries into a thriving dynamic modern and technologically developing economy, within a generation. The presence of requisite legal and legislative arrangements has contributed considerably to success. The lesson is clear: leadership is key to the generation of S&T research capacity and initiating and sustaining of technological development in any SSA country today.

Also worthy of mention are handicaps in the areas of management and institutional settings (see Box 4). These tend to be frustrating and structurally dysfunctional. After all, most public research institutions were set up during the colonial period and have not been modified to reflect post-independent realities.

Abject poverty

The poor and destitute cannot be a source of revenue to support the development of S&T research capacity. On the contrary, they constitute a burden on the exchequer so that society can ill afford setting aside adequate funds and other resources for the S&T effort. At the same time, the very poor also tend to have very low levels of literacy. Such populations would have little appreciation for S & T and the benefits it brings.

Box 3 : Weak property protection and porous regulatory regimes: losses of potential benefits to SSA

Sub-Saharan Africa's research and development capacities have suffered severe setbacks. In the main, they have allowed major financial opportunities to slip through their fingers, because of sloppy regulatory controls, and inadequate protective mechanisms erected for germplasm storage and exchange.

In Nigeria, local researchers at the International Institute of Tropical Agriculture (IITA) have been collecting germplasm for many years. These have included: palms, yam, cassava, herbs, shrubs and grasses. Over 20 years ago, researchers at the university of Ife had identified a sweetener called thaumatin found in a berry, which is widespread in nearby forests. Limited funding militated against the commercial exploitation of the sweetener estimated to be 1600 times sweeter than ordinary sugar. However, the prevalence of a porous regulatory regime and weak property protection, made it easy for the highly valuable germplasm to be pirated by unscrupulous research institutions abroad. This is exactly what happened: A British University got hold of the germplasm and cloned the protein now being used for the industrial production of the sweetener. A patent has also been issued to the overseas researchers who now claim legal rights to the ownership of the gene. Yet Nigeria, from whose forests the berry thrived through conservation efforts of indigenous communities, is not receiving a cent from the commercialization endeavour.

Nigeria has also been the source of another commercialised gene called the cowpea trypsin inhibitor. This protein which has a natural insect-killing ability, was cloned by a British University. The insecticide is now generating enormous profits for the overseas researchers with Nigeria receiving nothing. The failure to protect germplasm collections, coupled with an inability to argue strongly against biopiracy as India has successfully done in the case of neem and other indigenous resources, is undermining Africa's research capacities in terms of potential to benefit from successful inventive work.

Source: Walgate, R. (1990) Miracle or Menace? Biotechnology and the Third World, The Panos Institute, London, pp. 161-162.

Apathy among the population

Apart from the grinding poverty of the masses in SSA, most of the people, both literate as well as illiterate, seem to be ignorant of the whole issue of S&T research and what it can do to their standard of living. Thus, for most, science is just something their children have to learn in school, and they do not know what technology is all about. There is therefore no culture of research and technology and hence no clamouring for S&T research in these communities. Therefore, for S&T research to flourish in SSA, there is need to develop a culture that appreciates science, research and technology.

Most of the research is carried out on specific commodities, especially those made for export and cash crops. Most of the research effort in Kenya, for example, is on coffee (through the Coffee Research

Foundation), on tea (through the Kenya Tea Development Authority) and sugar (The Kenya Sugar Authority). Other research efforts are focussed on the main food crops such as maize, potatoes and pulses under the auspices of Kenya Agricultural Research Institute (KARI).

This focus on commodity-specific research is a reflection of the colonial nature of most SSA economies. Many African economies are former colonies of the developed countries and during the colonial period they were developed (as export enclaves), to serve the economic interests of the colonising countries. Nigeria, for example, developed as an exporter of palm oil and tin; Ghana, cocoa and aluminium; Ivory Coast, cocoa and coffee; and Kenya and Tanzania, coffee, tea and sisal.

These crops were largely grown under plantation agriculture, and the plantations were owned in most cases by huge multinational conglomerates, such as Brooke Bond and Delmonte. These multinationals, largely initiated much of this research in order to improve the yield and quality of the export crops. After independence, the research was taken over by the emerging nations, but continues to be crop specific.

Since research in much of SSA is crop specific, only the major crops are covered and most of the minor ones in terms of commercial agriculture are neglected[11]. Thus, very little research is undertaken on such crops like millet, sorghum, cowpeas, greengrams, finger millet, pigeon peas, cassava, sweet potatoes and yams.

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[11] There is no comprehensive data on wide-ranging cases based on original research. It would be interesting to undertake an Africa-wide study to see the trends and anomalies.

Box 4 The costs of missed opportunities: the case of the Ethiopian Endod

The failure of African institutions and governments to protect some of their most valuable, highly promising, and potentially lucrative R&D results, is a tragedy of horrendous proportions. This weakness means that the institutions concerned lose momentous opportunities to tap into sources of significant financial returns. Tragically, the financial benefits flowed elsewhere.

The case of endod is particularly relevant in this regard. In more recent times, an indigenous plant in Ethiopia (that has been used for generations in a variety of ways), has suddenly become a subject of patent protection in industrialized countries. The story of endod rings in our minds with piercing familiarity as many other cases occur of indigenous plants, suddenly becoming the property of firms or other institutions in industrialized countries. The specific and generic uses of some plants have been known in indigenous communities for years, but this knowledge abruptly belongs to somebody else. Such declarations are received with impunity in industrialized countries. Usually, the plants are subjected to 'scientific testing' and 'systematic verification' and the data which such laboratory activities produce tend to justify ownership. What is not really appreciated is that the data only tends to confirm what has already been known for generations. A few studies here and some clinical tests there become the basis of what are considered as 'original discoveries'. With this data (derived from knowledge hitherto well-established) and a little of 'scientific coating' of facts already known, property rights change places.

This is exactly what happened to endod. The berry was known to indigenous community members for ages in Ethiopia before systematic studies began to be carried out by Ethiopia's own 'son of the soil', Dr. Aklilu Lemma. Lemma's research sensibilities were aroused when he noticed an abundance of dead snails at a point where the use of endod in laundry work was common. It became apparent that the endod powder had a fatal impact on snails, the deadly carriers of schistosomiasis and bilharzia. With this discovery, Lemma made efforts to develop a low-cost molluscicide after extensive field trials in Ethiopia. His endeavours were geared to replace the expensive chemical synthetics imported from industrialized countries. One of the remarkable characteristics of endod is that it could be widely grown, was easy to process, and was cheap to cultivate. It is also a natural detergent, soap and shampoo. This fact is interesting in that the berry powder is biodegradable in 24 hours. Nature has its own answer to a lethal problem.

The institution that slowed down Lemma's progress and even delayed its widespread application in Africa was none other than the World Health Organization (WHO) itself. WHO insisted that the data emerging form Ethiopia was unscientific at best and unreliable at worst. Only data coming from well-established medical research centres can be beyond reproach; the developing countries are not known to possess research centres with such repute and data produced in these countries was not considered to be reliable. This attitude to research work emanating from developing countries is most unfortunate. It is responsible for scientific retrogression in Africa and many countries in the South.

Box 4 contd.

Lemma himself is irritated by this widespread mentality. He notes:

'The root problems of research in Africa are not only lack of adequate facilities and funds, but also the biases and reservations of some individuals and organizations in industrialized countries, who find it difficult to accept that any good science can come from our part of the world.'

It also needs to be mentioned that property institutions in industrialized countries are also stacked against property regimes existing in the South. These biases and reservations have thus had a reinforcing effect on each other.

Source: Khalil, M.H. (1995) "Biodiversity and the Conservation of Medicinal Plants: Issues from the Perspective of the Developing World" in Intellectual Property Rights and Biodiversity Conservation,Swanson, T. (ed.). Cambridge University Press, Cambridge, United Kingdom, pp.246-248.

Also, very little or no research is undertaken on minor fruit and vegetable crops such as papaya, guava, passion fruit, and peas. Indigenous fruits and vegetables have more less been ignored completely. This is an unfortunate state of affairs since such crops may be of little commercial significance. However, they are important subsistence crops and play an important role as food sources for most people in the SSA region and for their survival, especially, in times of extreme hardships.

Much of the research in SSA countries is in the hands of public institutions. The private sector plays an insignificant role in the funding, choice of emphasis, and execution of research of the region. However, in the last two decades, many SSA countries have experienced severe economic hardships with the result that their budgetary allocations to S & T capacities have declined sharply to mere pittance. This means that S&T research in these countries has become negligible.

Since much of the research of SSA states is carried out by public institutions, most researchers are civil servants. As such, they are subject to the low wages and other unattractive remunerations that obtain in the public service in Africa. The pay packages are so low that the researchers have no incentives to work hard and be productive. This means that there is very little to show in the way of results even for meagre resources deployed to support the research in these institutions. Thus, while adequate funding levels would be crucial, it is essential to note that the institutional and managerial dimensions of research organisations need to be adequately addressed to generate optimum reults.

There is a general absence of scheme to reward researchers who are productive in the form of innovations and inventions. Indeed, promotions and other forms of career advancement for researchers from these institutions are based on nepotism, bribery, tribalism, and other non-objective considerations. Many researchers in SSA countries become dispirited, disillusioned and discouraged and hence unproductive. As a result, S&T research output in most SSA countries is negligible.

Many universities in SSA carry out considerable research especially in agriculture and animal husbandry. However, the research in universities is motivated by academic pursuits and is not directed towards serving the R&D

needs of society. The result is that research has led to negligible impact on the technological progress of the African countries. Even in cases where potentially beneficial breakthroughs have been made, there has been little follow-up in the form of dissemination of the ideas and products involved. This means that the benefits accruing have been few and far between.

Lack of adequate funds has been a major constraint to S&T research in most research institutions and universities in SSA countries. As a result, these societies continue to lag behind the rest of the world in technological development.

Many countries in the SSA are seriously underdeveloped with respect to information technology (IT). Consequently, research institutions lack adequate computer hardware and software as well as the requisite personnel to operate them. This is a serious limitation to the development and expansion of S&T research capacity.

There is a general lack of qualified scientists especially in specialised areas in many SSA nations. Consequently, research in areas such as genetic engineering and manipulation is seriously constrained. This general shortage of highly skilled scientists and researchers is partly caused by the brain drain from Africa to the developed countries. They leave in search of better wages and working conditions and also to escape oppressive regimes[12]. These considerations mean that it is nearly impossible for SSA countries to develop meaningful capacity in S&T research. Other concerns are as follows:

- That researchers have inadequate understanding of the strategies that farmers use (commonly called indigenous knowledge).
- Research has for a long time lacked consideration of external factors such as markets, credit, financial, and general policy that condition farmers' attitude towards risk.
- Some researchers lack understanding of the difference between statistical use and risks to livelihoods as perceived by farmers.
- Poor coordination with and between field centres.

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12 Again, no work has been undertaken on an Africa-wide basis to determine the areas vital for indigenous capacity-building. This could form an interesting research undertaking.

Chapter Seven

Profile of Industrial Technological Capacities in SSA

It would be useful to distinguish the major types of technological capabilities in order to see what specific and generic competences various SSA economies have built over the years (Annex 8). The main ones are: production, investment and innovation capabilities. Production capability refers to the existence of skills, knowledge, and experience, to operate and maintain production facilities

On the other hand, investment capability refers to the availability of skills, knowledge, and experience, to design and reproduce production facilities for investment locally or abroad. Finally, innovation capability refers to the existence of skills, knowledge and experience that can improve and modify existing production facilities, to enhance efficiency or accommodate domestic inputs. SSA countries have succeeded in generating production capabilities in a wide range of manufacturing activities (Table 6). Most of these were established in an effort to satisfy obvious local demand, hitherto fulfilled by in-flowing imports. The basic trend involved the production of essential consumer and intermediate goods, such as matches, nails, soap, iron, pipes and iron sheets, hence the pattern of import substitution industrialization. With regard to technological capacities, the status of institutions in SSA can be summarized in Tables 7 and 8 (see also Box 5).

Table 6: Production Capabilities in Selected SSA Countries

Producing Country	Products
Angola	Fuel oil, coffee
Cameroon	fuel oil, cocoa, timber
Congo	fuel oil, timber
Gabon	fuel oil, timber
Nigeria	fuel oil
Seychelles	fuel oil, fish, copra, spices
Burundi	coffee
Central African Republic	coffee, diamonds, timber, cotton
Madagascar	coffee, cloves, vanilla
Rwanda	coffee, tin, livestock
Tanzania	coffee, cotton, hard fibres
Uganda	coffee, cotton
Cote d'Ivoire	cocoa, coffee, palm oil, fuel oil
Equatorial Guinea	cocoa, timber, coffee
Ghana	cocoa, bauxite, timber
Sao Tome	cocoa
Benin	cotton, cocoa, palm oil, fuel oil
Burkina Faso	cotton, vegetable oil, livestock, groundnuts
Chad	cotton, livestock
Mali	cotton, livestock
Sudan	cotton, vegetable oil, livestock, groundnuts
Gambia	groundnuts
Guinea-Bissau	groundnuts, cashew nuts, palm oil
Senegal	groundnuts, fish, phosphates , fuel oil
Cape Verde	fish, bananas, fruit
Mauritania	fish, prawns, sugar, cotton
Mozambique	fish, prawns, sugar, cotton
Senegal	fish, prawns, sugar, cotton
Mauritius	sugar
Reunion	sugar
Swaziland	sugar, fruit, iron ore
Malawi	Tobacco, tea, sugar
Zimbabwe	Tobacco
Djibouti	Livestock, fuel oil
Somalia	Livestock, bananas, fruit
Mali	livestock, bananas, fruit
Botswana	diamonds, meat
Guinea	bauxite
Mauritania	iron ore, livestock, fish
Niger	uranium livestock, groundnuts
Sierra Leone	diamonds, cocoa, coffee, bauxite
Togo	phosphates, cocoa, cotton, coffee
Zaire	copper, coffee, fuel oil
Zambia	copper

Table 7: Status of Capacities for the assimilation of technology in Sub-Saharan Africa (SSA)

Steps involved	Capacities
Needs and capability assessment	
Resource assessment	
Technology forecasting and assessment	Except for a limited number of cases, most nationals capacities are not robustly disposed to build technological capabilities from imported technologies. This conclusion applies to points 1-11.
Demand assessment	
Identification of internationally available technologies	
Choice, evaluating and negotiating mechanism	
Investment for import	
Adaptation and production	
Commercialization	
Assimilation and upgradation	
R&D	Except for production capabilities, most capacities are generally weakly disposed to undertake prototype development and also investments in the local generation of industrial technologies
Prototype for national development and testing	
Investment for local generation	
Production	

Box 5 Nnewi as a success story: an emergent industrial cluster in Nigeria

Nnewi is a semi-urban town in Eastern Nigeria. It is a fast growing industrial complex in the heartland of the east, far removed from any major metropolis. It lacks access to the internal road network, is starved of piped water and communications, and has totally been ignored by the government. The community is constituted of highly motivated, daring, industrious , innovative and thrifty people, who have created a technological centre in their hometown, and changed almost unrecognizably the character of business for which they had hitherto been associated with in Nigeria over the years. At first, they were simple merchandizers, known to engage in trade and transportation. The process of advancement in Nnewi has followed the route, from an agrarian community (farmer) to trader (business) community and then to manufacturing (industrializing enclave). Three sectoral groups of production have been identified: (a) basic metal, iron /steel and fabricated metal products; (b) the electrical and electronics sector; and (c) the motor vehicles and miscellaneous assembly. Inspite of the different economic conditions in Nigeria and unlike many other large scale public enterprises, engineering firms at Nnewi are operating at a profit.

The reasons behind Nnewi's success can be classified into three. Firstly, the indepth knowledge on how firms acquire technology and address issues of technical change. Secondly, how small and medium enterprises can enhance prospects for competiveness and on the path of continuous productivity growth. Thirdly, the deep knowledge of exploiting strong networks of small firms, the promotion of division of labour and specialization through subcontracting, and the realization of the benefits of economies of scale and scope, and collective capability development. Geographical proximity enhances cohesion, interfirm transactions and institutional effectiveness. There is also the issue of cooperation, which does not seem to have affected rivalry and healthy competition. Information exchange could be formal or informal through institutions or interfirm technical exchanges. Relative easy access to capital, has led to widespread entrepreneurial dynamism. The existence of specialized production units that offer quality design, flair and innovation is as a result of flexibility of the firms. Trust and cultural affinity has been another factor to comment on the success of SME clusters. Cooperation rather than rigid and antagonistic employer - employee relation, has assured stability of clusters.

The clusters in East Nigeria do not have the level of skilled workforce found in European clusters, but high level enterpreneurship is exhibited in many of them. Nnewi clusters have also been characterized by informal credit and information sharing among firms.

Box 5 contd.

Most of the entrepreneurs have only elementary education, but before engaging in production, a relation would fund the training effort through an apprenticeship exercise. Kinship support and affiliation has defined the structure of trading and, subsequently, that of manufacturing. Most have adopted the strategy of keeping the skills and experiences gained within the family, while reducing the risk of losing a valuable worker. Trust between employers and employees has been critical for success. Employing relatives into the trading and manufacturing network has reduced the risk of sabotage and ensured some measure of loyalty. The widespread provision of private facilities such as water-boreholes, electricity, and communication facilities, have contributed to their success. Some entrepreneurs sponsored themselves to study factory operations in Taiwan, before making a commitment. On their return, most went ahead to import machinery and equipment. Services of engineering personnel were contracted for setting up the plant, while the entrepreneur closely watched. There was no state support for training; on-the-job training during production takes the form of 'close marking' of the foreign technical partners. This 'close marking' during the piecemeal procurement of machinery made them successful; they observed the entire plant assembly process. They mastered both the product and process technologies well. External training of start-up/pioneering staff was undertaken either in Taiwan or on-the-job. Instructions were given by the foreign technical partner. Some of the successful SMES are IBETO Group of Companies, Adswibch, Greatland Industries Limited, Godwinkris Industries Limited, G.O.D Brothers Company Ltd, Cento group of Companies, Omatha Holdings Ltd, Isaho Industries Ltd and John White Industries Ltd.

Other forms of learning included learning by doing during production and maintenance. Other significant determinants of technology development included competition, both local and foreign. A thorough understanding of factor inputs, their accessibility, availability and raw material costs, costs of components and spares, the level and pattern of demand, relative changes in factor prices, evaluation of domestic and foreign markets, structure of inputs and outputs, and technological markets had been built consciously and deliberately. Other vital factors that have contributed to success include, understanding the nature of technology and production prices, accessing technological information, exploring the availability and type of suppliers and customers, generating working capital and credit for investment, and the drive to succeed.

Table 8: Selected cases of small firm industrial clusters in Sub-Saharan Africa (SSA)

Country	Clusters	Activities
Burkina Faso	Ouagadougou	Motor vehicle repair, Tailoring, Electrical repair, Iron working, Grain milling
Ghana	Assi (Tamale) Tema (Accra)	Food processing, Metal working
Kenya	Kamukunji (Nairobi) Kisumu Embu	Agricultural imprents making , Metal working, Wood working,
Malawi	Blantyre	Food processing, Wood working, Textiles , Metal working
Nigeria	Awka Zaria Lagos	Iron working Leather works Wood working
Uganda	Katwe Jinja	Metal working

Source : Oyelaran - Oyeyinka, B. (1997) Nnewi: An Emergent Industrial Cluster in Nigeria, Technopol Publishers, Ibadan, Nigeria, p. 16.

Box 6 Innovation capabilities, expropriation and marginalization of domestic capacities: the case of geothermal development in Kenya

Some firms in SSA have generated minor innovations; the case of the Olkaria Geothermal Plant in Kenya is worth reviewing. Geothermal water is hot and therefore needs to be cooled to prevent thermal pollution. One way of cooling the waste water is to use mechanical drought towers. Mechanical draught towers brought additional problems which were not envisaged by the consultants, i.e. the failure of cooling tower grids to remain in place, because wooden hooks weakened and resulted in the grids falling off to the base of the concrete structure. After four years, Unit 1 of the cooling tower experienced grid collapse. The grids which were imported were made of treated wood. Orders were placed for replacement, but while the imports were being awaited, local wood was used instead. The highly corrosive acidic water dissolved away the replacements within a week, and compounded the problem of blockage of water distribution nozzles.

Olkaria sought assistance from a local timber firm, Timsales, to solve the cooling tower grid system. Timsales argued that the grids were made from wood treated with Chromated Copper Arsenate. This timber preservative is a poisonous chemical, inflammable and its use is prohibited locally. Domestic production of the grids was therefore impossible.

Olkaria used fibre-glass as a solution to the grid problem. This followed a suggestion by a technician who had observed that fibre-glass resisted corrosion. The trial fibre-glass grids were successful and Kenya Power and Lighting Company Ltd (KPLC) commissioned a local firm to design a jig and fabricate the product. This innovational development took place before the cooling tower erection for phase two. The consultants took this knowledge on board, and the tender specifications for phase two made explicit reference to a fibre-glass grid system. Olkaria phase two uses a home-bred innovation. The use of fibre-glass grids has not affected power output, but has increased performance because:

1. no more cases of blockage are reported,
2. forced outages due to collapsing grids have been eliminated altogether, and
3. the material was adopted and acceptable under KBS regulations.

Source: Khalil, M.H., 1992.

Box 7 Non-existing or incompetent technology screening agencies: the case of technological modularization

Energy technologies are getting more and more sophisticated. The choice of modular technology for the prospective phases in Olkaria geothermal development will have adverse technological implications. Many KPLC engineers pointed out that the decision by Ewbank Preece and Partners to invest in a modular technology, should have been received for technological and capacity building reasons. They stated the following objections: First, because the sub-modules consist of parts locked into each other and fitted together at source, the knowledge about the nature of these parts, their systemic interdependence, and their interlocking arrangements has not gained first hand. Secondly, there is limited flexibility and access to repair and maintenance of modular assemblies. There is limited room for manoeuvre, because of their structural compactness. Constraints of space adds to the gravity of the technological learning process. In fact, the compactness is meant to cut down on repair and maintenance. The sub-assemblies and sectional wholes have to be removed and a new equivalent fitted as replacement. Thirdly, stock-holding for modular products is difficult to achieve, because of lack of standardization with the more conventional technologies. Some KPLC engineers observed that if the phase three technology was conventional (like phases one and two), then interchanging and stock holding would be a lot easier. Fourthly, manpower sourcing for non-conventional, modular technologies is limited. This aspect not only marginalizes the repair and maintenance capabilities built in earlier phases, but also risks being exposed to monopolistic suppliers. Fifthly, training is too specialized and will be of scant value to knowledge required for the existing conventional system. As such, the cumulative technological experience obtained during operations of earlier phases cannot be brought to bear on subsequent phases.

Source: Khalil, M.H., 1992.

Chapter Eight

Vital Lessons for Bilateral and Multilateral Institutions

The foregoing review of a few selected cases of technological capacities in SSA countries does not tell us much about the range and diversity of capabilities existing in the region as a whole. They offer some interesting and penetrating insights on some riveting examples of technological success (see Box 6) and some sad cases of technological failure. At the same time, many cases offer us only a glimpse of the numerous obstacles (see Box 7) that have stood in the way of potentially promising technological developments. At any rate, what the cases of success and failure reveal are the opportunities and risks inherent in the evolution of domestic and technological capabilities. They also point to the possibilities posed by the technology acquisition process.

More importantly, however, has been the revelation that SSA countries lack the baseline information on existing technological capacities within their own borders. That is, most states have not designed a robust system aimed at building comprehensive profiles of available technological capabilities. The information that is available is scattered in studies and reports, most of which only indirectly inform us about existing competences.

In short, SSA countries have had no tradition of building profiles of existing technological capabilities. Moreover, they have not directed any effort in assessing national technological gaps and levels; these by derivation, being drawn from an assessment of important human needs. Since these tasks have not been undertaken, and, therefore, not yet institutionalized, SSA countries have not been able to establish running programmes for assessing national technological needs. In summary then, Africa's prospects for technological change will begin to rest on sound foundations, if they embark on the following:

- Assessment of national resource profiles.
- Assessment of national technological capabilities, gaps and levels, areas of relevance and needs.
- Building of capacity quality control and standards.

In all fairness, most SSA countries have data on the national resource profiles; the information has typically covered the quantities of natural resources. However, the information is not comprehensive enough as to be of great value. Determining stocks and flows and their quality would be indispensable, but this would only form a part of the profiling process. With respect to national technological capabilities[13], it would be crucial to build information on the quantity and quality of human resources (Annexes 1-3) such as:

- managers and engineers,
- technicians and skilled workers,
- craftsmen, semi-skilled, and other workers, and
- inventors and innovators.

In addition, the assessment exercise should include profiles of technical resources (Annex 4), such as equipment, tools and machines (general and specific). It should also cover institutional resources comprising of departments, industrial units, public agencies, enterprises, and their linkages, and national linkages Annexes 5 and 6). Lastly, the assessment task should address informational resources, such as manuals, brochures, blue prints, operating and maintenance booklets, design and technical data.

Now, as SSA countries embark on this stage, they should carry out a further assessment of national technological capabilities in a standard, systematized format to classify the technological capacities (Table 9).

Once these tasks are accomplished (assessment of national resources and capabilities), the other types of assessments mentioned earlier should then follow. But at present, SSA countries could very well be advised to proceed with these foundational profiles.

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13 Technological profiling comprises of assessments in human, technical, institutional and informational spheres.

Table 9: A standard classification format for assessing national technological capabilities

Type of capacity	**Example**
Cultivating	Agriculture, livestock, forestry
Gathering	Natural gass, oil, fishing
Pre-processing	Grain milling, manufacture of paints and ganishes
Processing	Sugar factories, refineries
Manufacturing	Spinning, weaving, finishing textiles, production of metal products
Assembling	Manufacture of apparel, containers, and oxes and paper board
Packaging	Canning and preserving fruits, vegetables, soft drinks and bottling of carbonated water
Constructing	Construction
Distributing	Electrical power
Supporting	Ship reparing, transport and banking

Source: adapted.

It is evident why a comprehensive review and status of S&T capacities in SSA is very difficult to build from scattered studies and reports. The reason for this is that Africa has yet to proceed with the most basic tasks of technological endevour[14].

[14] Most of the issues on science were covered in the early sections of this report. That is why I noted the need to develop a robust regime of science indicators in all the areas I had mentioned.

Chapter Nine

The Brain Drain and Erosion of S&T Capacity in Africa[15]

The African Capacity Building Foundation has estimated that Africa is losing an average of 20,000 skilled personnel a year to developed countries. About 128,000 Africans have emigrated to the USA alone over the last two decades (Annex 7). The largest migratory flow from Africa to the USA has been from Egypt (25 %), Ghana (26%), and South Africa (8%).

African professionals moving to settle abroad are depriving the continent of much-needed skills. World Bank estimates indicate that Africa is presently employing about 100,000 expatriates from industrialized countries. Their cost is equal to US $4 billion equivalent, about 35 per cent of the total official development assistance flowing into the SSA countries.

Several factors have been attributed to the migration of highly educated individuals. There appears to be two forces at work, the push-out and pull-in factors in Table 10.

In 1998 alone, at least 120 doctors left Ghana for the USA. It is estimated that about 600 Ghanaian physicians are working in the USA presently, constituting 50 per cent of Ghana's skilled medical practitioners[16]. Nigeria has at least 10,000 academics working abroad. Estimates show that about 40,000 African nationals with doctorates are operating in industrialized countries[17].

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15 Data for this section was derived from Aredo, D. (2002) "Human Capital Flight from Africa: An Assessment of Brain Drain in Ethiopia". Paper Presented at the Regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia. Moreover, this report concentrated on brain drain to countries outside Africa. No report exists to show movement to other African countries.

16 ibid, Sethi, (2002), p. 3.

17 ibid, Sethi, (2002), p. 3

Table10: Some push and pull factors affecting brain drain

Push Factors	Pull Factors
Low wages adn salaries	Higher wages and income
Political instability	Higher standard of living and better way of life
Over-productionand under-utilisation of qualified manpower	Allocation of substantial funds for research Technological gap
Lack of research and other facilities	Modern educational system and better career opportunities
Discrimination in appointment and promotion	Prestige of foreign training
Lack of Freedom	Better working condition and employment opportunities
Lack of satisfactory working conditions	Intellectual freedom
Lack of scientific tradition	Relative political stability
Desire for higher qualifications and recognition	Presence of a rich, scientific and cultural tradition
Better career expectations	Availability of experienced supporting staff
Public apathy	Motivational factors and recognition

Source: Adapted by Aredo, D. (2000) "Human Capital Flight from Africa: An Assessment of Brain Drain in Ethiopia". Paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia, p.7.

It is estimated that the Ethiopian Diaspora in the USA alone numbers about 250,000 with at least 50,000 residing in Washington alone[18]. Looking at Table 10, it is evident the number of Ethiopian non-returnees sent abroad to study has increased over time. As the table reveals, the average rate of staff non-returnees has been around 35 per cent.

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18 Aredo D. (2002) "Human Capital Flight from Africa: An assessment of Brain Drain from Ethiopia". Paper presented at the regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia, p. 10.

Table 11: Profile of Ethiopian staff from case study institutions not returned home

Study Period	AAU 1981/2 - 1994/5	ESTC 1986/7 - 1995/6
Percentage of non-returnees	35	41
Fields with higher % of non-returnees	Medicine (43%)	Technology (56%)
Programme of study with highest % of non-returnees	Ph.D. and Specialization (42%)	Certificate Ph.D. (100)
Major host countries	West Europe (42%)	West Europe (94%)
Major donors	Institutions (68%)	NA

Source: Adapted by Aredo, D. (2000) "Human Capital Flight from Africa: An Assessment of Brain Drain in Ethiopia". Paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia, p.19.

These trends have certainly had a negative impact on local capacities. The ambition to build S&T capacities in Africa would require putting in place conducive pull-in conditions of the type enumerated in Table11. Political reforms, good governance, democratization, conflict prevention and resolution, the strengthening of civil society, and the re-appraisal of technical assistance regime, should be given priority.

Figure 2: Extent of migration from SSA to USA

Chapter Ten

Solation and Obsolescence of Researchers

A number of agricultural research institutions in Africa have established extremely strong connections with research institutions elsewhere in the developed world. In fact, the connections have largely involved germplasm collections and attempts by international research centres to secure access to stored collections. However, over the last decade, linkages with counterpart researchers abroad has declined considerably, apart from a minute number of selected cases (Table 12), overall, linkages and collaboration between researchers has been poor and so has international networking. International exchange programmes, sabbatical engagements, and short term career enhancement awards have nearly all been cut back or abolished completely. Participation in fellowships and international symposia and conferences has almost ground to a halt. Lack of funds has been the oft-cited reason for this notable decline. Government budgets do not cater for travel to international conferences.

Moreover, many national research organizations, except of course the international agencies such as ILRI and ICIPE, have not been able to keep abreast with professional scientific and technological developments elsewhere, because membership to international organizations and subscription to journals of great worth, have fallen drastically. At the same time, African researchers have not been able to consistently link up with their peers abroad using electronic mail, because of the expense involved. The facilities are declining in cost, but still the sums involved strain the personal budgets of the researchers. In most cases, most universities have found themselves hard-pressed in maintaining these facilities. On average, less than 1 per cent of researchers are capable of sustaining regular professional contacts with peers elsewhere[19]. Yet, it needs to be pointed out that linkages between African institutions themselves are few and far between. This is generally true whether the focus is national or regional.

19 See ibid, Aredo, 2000, p. 32.

Table 12: Summary statistics of staff who left for studies abroad from AAU and ESTC, 1981/82 - 1996/97

YEAR	AAU		ESTC	
	L	NR	L	NR
1981/82	33	1	NA	NA
1982/83	61	2	NA	NA
1983/84	74	6	NA	NA
1984/85	91	22	NA	NA
1985/86	85	15	NA	NA
1986/87	90	24	4	-
1987/88	110	20	16	5
1988/89	79	22	8	3
1989/90	76	32	23	8
1990/91	83	37	11	4
1991/92	60	53	13	10
1992/93	80	45	NA	NA
1993/94	76	56	NA	NA
1994/95	9	20	NA	NA
1995/96	NA	NA	1	1
1996/97	NA	NA	NA	NA
Total	1,007	355	76	31
%	35		41	

Source: Adapted by Aredo, D (2000) "Human Capital Flight from Africa: An Assessment of Brain Drain in Ethiopia". Paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia, p. 32.

Chapter Eleven

Strenghths and Weaknesses of Technological Capacity Building

Africa's general strengths lie in the existence of institutional arrangements already disposed to scientific research (Annex 8). Indeed, if collaboration with the private sector and the international research agencies could be enhanced, many public agencies would brighten their prospects for research.

Also to be mentioned is the orientation of many research agencies. These have largely focussed on research that has been demand-driven. Human resources have been developed with this particular feature in mind.

The major weaknesses that inhibit the development of S&T include:

- lack of a comprehensive set of science and technological indicators to guide action and monitor progress.
- ineffective planning, programming, disseminating and coordinating functions of research institutions.
- poor utilization of R&D results.
- limited resources to train adequate manpower followed by non-customized training.
- poor renumeration of scientists, engineers, and other auxiliary staff.
- general obsolescence of infrastructure, research facilities, and other support facilities.
- limited inter-institutional collaboration at the national and regional level.
- limited participation by the private sector in S&T activities.
- lack of inspiring leadership.
- favouritism in allocation of rewards, scholarships and fellowships.
- poorly disposed assessing of technological opportunities and screening of appropriate technologies.

The potential to build technological capacities has largely been constrained or undermined by the following factors:

- tied aid and purchases that undermine the ability of domestic economies to increase domestic content.
- failure to exploit public domain technologies.
- lack of tradition of analyzing patents and patent histories of basic innovations.
- commitment to science and technology more rhetorical than real.
- poorly disposed and rationalized institutional structures to promote technological development.

- misleading conceptualization of the science and technology relationship.
- no sustained national short-term course on technology acquisition where success stories are analyzed and cases of failure evaluated.
- political interference and corruption by local leaders.
- the conduct of export credit agencies in oversees countries.
- lack of knowledge on the part of domestic negotiators on what technological capacities to build and how to build them.
- trivialization of pre-investment, and project execution and implementation services.
- poor preparation and ill information on the part of domestic negotiators.
- cred control to overseas consultants, contractors and suppliers of technology.
- marginalization of professionals, experts and specialists in negotiations.
- restrictive and conditioning policies of multilateral and donor funding institutions.
- ineffective and poorly designed policy framework to actively guide and influence the evolution of robust competence.
- non-existing or patchy databases on national technology profiles and domestically available technological competencies and technology profiles.
- absence of robust strategies and programmes to increase domestic content.
- a non-existing tradition for active search of diverse national, regional and international options, opportunities and sources of techno-industrial capabilities.
- existence of national lame-duck institutions to screen technology agreements.
- absence of ethos and traditions to actively acquire technologies.
- weak engagement or non-involvement in pre-investment activities.
- absence of visionary leadership in technological matters.
- institutional dispersion and dysfunction.
- lack of organized training in technology management and technology policy disciplines.
- absence of integrated techno-industrial strategies.

Chapter Twelve

Gaps that Need to be Given Priority

This study has noted two major gaps that have militated against the development of strategies crucial towards spearheading technological advance in SSA countries:

1. the absence of a comprehensive system of S&T indicators. The immense benefits of the latter were identified earlier
2. the absence of comprehensive technological profiles stemming for lack of assessments of the following:

   - national resource profiles, and
   - national technological capabilities,
   - gaps and levels,
   - areas of relevance and
   - needs.

Bilding capacities in these areas is pivotal if SSA countries are to forge a technology policy framework, caable of guiding the private sector and stimulating wider technological change. These tasks would transform industrial policies from being technologically benign to being technologically catalytic.

The areas that SSA needs to pay particular attention to, include: renewable energy research; technological reearch into equipment design, machinery fabrication, and engineering hardware; and tlecommunications, electronics, computer hardware, and all aspects of information technology. Table 13 covers the key domains that the continent should begin addressing in earnest.

In the acquisition of development of S&T capacities, Africa should concentrate her efforts in the following broad areas[20]:

- food production and security,
- energy (renewable),
- housing,
- transport,
- health (HIV/AIDS),
- telecommunications and information technology, and
- environment (water).

20 These areas could have public as well as private components. At any rate, a needs assessment would have to be carried out to determine the specific foci at national and regional levels.

Chapter Thirteen

Recommendations

1. The first thing that bilateral and multilateral institutions could do is to assist SSA countries establish a comprehensive, uniform and standardized framework of science and technology indicators. This would entail building capacity in S&T data base management. The unit responsible for S&T data collection, storage and retrieval should be set up and located in the relevant government departments involved in statistical compilation and dissemination. A consultant could be identified to coordinate the programme and assist in the preparation of questionnaires that would contain details of the various S&T measures and the tabular formats they would take. These would then be made to appear in the regularly consulted national statistical documents. National and regional workshops could be held to harmonize efforts and facilitate the process. A five-to-ten year project, divided into several stages, can be formulated to build and maintain a comprehensive S&T system of indicators and database management. Indeed, IDRC is well placed to spearhead such a programme on an SSA-wide scale.

2. Bilateral and multilateral institutions can establish viable national and regional screening agencies to monitor, identify and evaluate promising research results emanating from R&D institutions. Funding could then be targeted to facilitate the stages of development and commercialization. Particular interest should be on those R&D inventions with promising prospects for industrial application. The lost opportunities stem from the expropriation of thaumatin, endod and the cowpea trypsin inhibitor, because local funds for industrial development and commercialization were not forthcoming.

3. National capacities for guidance or actual involvement in technology acquisition are either very weak or non-existent in SSA countries. This has been very costly for several countries if the numerous publicized scandals and investment frauds are anything to go by. Bilateral and multilateral institutions should embark on a robust capacity building programme that would entail customized and tailor-made training in technology acquisition in all its diversity. Most people see this in terms of foreign direct investment, licensing, or outright sales (turn-key), but they are sadly mistaken. The human, technical, informational and organizational requirements are phenomenal, and these need to be tackled step by step. Donor agencies could also support short-term national courses in this area.

4. SSA countries should concentrate on building robust national science and technology (S&T) systems. They should include the following elements:
    - Policy framework for training of people at all levels. These may include managers, researchers, engineers, technologists and technicians.
    - Stimulation policies for technical change within enterprises. These should be both radical and incremental.

Table 13: Gaps in science and technological research in Sub-Saharan Africa

Prospective Field	Sub-fields
New Materials	Advanced composite materials; Alloys/metallic compunds; Fine ceramics; Carbon materials; Amorphous materials; Highly pure polymer materials; Silicon chemical materials
Electronics	Microelectronic materials; Superconducting devices; Power electronic elements; Large area circuit elements
Biotechnology	Animal and plant cell engineering; High performance enzymes and biomaterials; Genetic engineering; Bio-databanks; Screening and isolation of genes from all sources; Bioreactor technology
New Materials/electronic-related technologies	Metallic and inorganic material process technology; Precision molecular alignment technology; Evaluation, analysis and measuring of technology; Processing technology for extreme environments; Protein alignment technology; Biomembrane technology; Analysis of bio-related materials
Bioelectronics	Bio-mimicking materials; Biocompatibility materials; Biochemicals technology; Bioprocessing
Biomaterials	Self-organized data procesing systems; Self-organized neural works; Ultraparallel processing architechture; Integrated mechanical control softwre; Software development technology; Disaster prevention technology; Environmental control technology; Human-related technology; resource and energy technology; Robotic technology; Flexible computer integrated manufacturing; Intelligent processing equipment; Systems management technologies; Energy technologies; Pollution minimization, remediation, and wastage management; Microelectronics: logic chips, micropre cessors, Submicron technology
Computer Software and Systems engineering	Electronic controls: a) Sensors Informatin storage: a) Magnetic information storage software, b) Applications software, c) Artifial intelligence Computer modelling and dimulation; Expert systems; High-level software languages; Software engineering; Computers: a) Hardware integration b) Operating systems c) Processor archtecture Human interface and visualization technologies: a) Animation and fullmotion video b) Graphics hardware adnsoftware c) Handwriting and speech recognition d) Natural lanugage e) Optical character recognition Database systmes:a). Data representation, b). Retrieval updata, c). Semantic modeling and interpretation. Design and Engineering tools: a) Computer-aided engineering, c) Human factors engineering, c) Measurement techniques, d) Systems engineering. Commercialization and production systems: a) Computer-integrated manufacturing
Manufacturing	Process Equipment: a) Advanced welding, b) Joining and fastening technologies Networks and Communications: a) Broadcast switching b) Digital infrastructure, c) Fibre optic systems Portable Telecommucations equipment and systems: a) Digital signal processing b) Transmitters and receivers
Electronic components	
Energy and environment	
Information technologies	
Engineering and production technologies	

- There should be effective integration of governments' S & T policies with its economic and social policies.
- There should be policies regarding the organization and funding of research, development systems and institutions, besides networks.
- There should be policy frameworks accounting for good governance and accountability of institutions within the S & T systems.
- There should be policies that protect public interests and at the same time link research system and the productive sector.
- Transparent and accountable structures should be established for overall policy management of S & T over the long term.
- Promotion of unimpeded flows of scientific, economic, social and technical information, nationally, internationally and regionally.
- Establishment of a basis, whereby the entire community is given opportunity in the formulation of options for public policies.

The one area that SSA countries need to build technological capacity is renewable energy. Wind, solar, geothermal, and biomass energy subsectors are growing rapidly around the world with estimates indicating that their contribution to energy supply could reach 50% by the year 2050. Through cooperative arrangements, several countries can band together to exploit the economies of scale.

Opportunities for intra-regional specialization can also be explored. Wind, solar and biomass technologies or vital components and related parts, can be spread out in cost-effective ways. Given prospects for growth and significance for sustainable development, African countries can join forces to build production, investment and innovation capabilities.

South Africa and Zimbabwe have built significant capabilities in solar and photovoltaic technologies, but to meet the growing energy needs within their own borders, national investment capacities will have to be expanded considerably. Both South Africa and Zimbabwe can assist several blocs of African countries to establish significant capabilities in specific renewable technologies, where domestic competence is clearly evident. Leading companies around the world could be engaged in the generation of technological capacities.

In the field of wind energy, for example, SSA can be selective in the choice of capacities they wish to build. These range from the design, development and manufacture of wind turbines, components, blades, generators, gear boxes, towers and wind sensors. Technological capacities will also have to be built in the service sector — installation, maintenance and engineering.

Bilateral and multilateral institutions can promote interest in renewables, prepare baseline studies and feasibility reports on the prospects for renewable energy investments in all their diversity. In particular, they can focus on supporting those technologies that would have the greater impact on regional and rural development. These include: small scale wind generators, solar systems and other promising stand-alone applications. Achieving sustainability is an indispensable goal if livelihoods and the quality of life of citizens in Africa are to be improved. In this transition, the building of energy capacities would be pivotal.

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Annexes

Annex 1: Comparative Distribution of R&D Personnel in SSA in 1988 (excluding South Africa)

Category	%
Researchers	15.50
Support Professionals	10.10
Technicians	18.60
Auxilliary staff	52.00
Unallocated staff	3.80

Annex 2: Specialization of R&D Centres in SSA in 1998 (excluding South Africa)

Field	%
Agriculture, forestry and fisheries	47.00
Health and nutrition	10.50
Energy, geology andmining	5.60
Manufacturing	6.70
Environment	7.40
Basic Sciences	1.60
Social and human sciences	12.30
Milti-disciplinary	8.90

Annex 3: Personnel Engaged in R&D by Category of Personnel

Country	Year	All R&D personnel	Technicians and equivalent staff		Other Supporting Staff		Researchers	
			MF	F	MF	F	MF	F
Benin	1989	2687	242	64	1652	339	794	100
B. Faso	1997	780	165	16	439	-	176	34
Egypt	1991	102296	19607	-	56274	-	26415	-
Mauritius	1992	1162	170	-	603	-	389	-
Nigeria	1987 1986	12880 12845	6042 6005	- -	5500 5341	- -	1338 1499	- -
Senegal	1993 1994 1995 1996	84 83 76 78	32 32 28 29	9 8 7 7	32 32 29 30	- - - -	20 19 19 19	5 6 5 5
S. Africa	1987 1989 1991 1993	20557 18175 22223 60464	5600 4584 5006 11343	- - - -	3488 3672 5115 11929	- - - -	11469 9919 12102 37192	- - - -
Uganda	1993 1994 1995 1996 1996	708 800 860 890 950	215 244 298 285 272	25 18 23 27 34	195 212 200 219 256	- - - - -	298 344 362 386 422	94 122 136 149 162

Source: UNESCO (1999) Statistical Yearbook.

Annex 4: Selected R&D Indicators in African Countries

Country	Year	Personnel engaged in R&D			Expenditure for R&D		
		Researchers per million inhabitants	Technicians per million inhabitants	Number of technicians per researcher	Per capita (in national currency)	As % of GNP	Annual average per researcher (in national currency)
Benin	1989	176	54	0.3	-	-	-
B. Faso	1995 1996 1997	- 16 17	- 15 16	- 1.0 0.9	81 196 240	0.08 0.17 0.19	- 12932444 14695807
Burundi	1984 1989	25 33	20 32	0.8 1.0	38 101	0.15 0.31	1519272 3154042
CAR	1984 1990	78 56	66 32	0.8 0.6	268 -	0.25 -	3473424 -
Congo	1983 1984	435 462	- 789	- 1.7	19 14	0.01 0.01	42718 29618
Egypt	1995 1996	- -	- -	- -	7 7	0.22 0.22	- -
Gabon	1986 1987	255 234	25 22	0.1 0.1	1 -	0.01 0.01	2256 1801
Libya	1980	362	493	1.4	8	0.22	20796
Madagascar	1995	-	-	-	1636	0.18	-
Mauritius	1992	361	158	0.4	-	-	-
Nigeria	1987	15	76	5.3	2	0.09	75809
S. Africa	1993	1031	315	0.3	72	0.70	69750
Uganda	1997	21	14	0.6	-	-	-
Senegal	1996	3	4	1.5	48	0.02	21587369

Source: UNESCO (1999) Statistical Yearbook.

Annex 5: National Research Centres in Africa, 1998*

Country	Total	A,F,F	H,N	E,G,M	M	E	BS	S, HS	M
Angola	3	1	-	1	-	1	-	-	-
Benin	5	4	-	-	-	-	-	-	1
Botswana	7	2	-	-	2	-	-	1	2
Burkina Faso	6	1	1	1	-	-	-	1	2
Burundi	5	3	-	-	2	-	-	-	-
Cameroon	27	12	2	5	-	2	-	4	2
Cape Verde	1	1	-	-	-	-	-	-	-
C. Afr. Republic	4	2	1	-	-	-	-	-	1
Congo	5	1	-	-	-	2	-	-	2
DRC	9	2	-	1	-	2	-	2	2
Cote d'Ivoire	17	5	1	2	2	2	1	2	2
Ethiopia	42	25	10	1	-	1	3	2	-
Gabon	14	4	1	-	2	3	-	2	2
Gambia	2	1	1	-	-	-	-	-	-
Ghana	23	9	2	-	3	3	-	5	1
Guinea	3	1	1	-	-	-	-	-	1
Kenya	29	14	4	-	4	2	1	3	1
Lesotho	2	-	-	-	-	-	-	2	-
Liberia	4	1	1	-	-	1	-	1	-
Madagascar	4	-	1	1	-	2	-	-	1
Malawi	20	18	-	-	-	-	-	1	-
Mali	6	2	2	-	-	-	-	-	2
Mozambique	4	1	1	-	1	-	-	-	1
Namibia	3	-	-	1	-	1	-	-	1
Niger	4	1	-	-	-	1	-	1	1
Nigeria	35	21	2	2	4	-	-	6	-
Rwanda	5	2	1	1	-	-	-	-	1
Senegal	20	10	2	-	-	1	1	4	2
Seychelles	2	-	-	-	-	-	-	1	1
Sierra Leone	3	1	-	1	-	-	-	1	-
South Africa	172	30	31	11	21	6	17	37	19
Sudan	9	1	3	-	1	1	-	2	1
Swaziland	6	3	-	1	1	-	-	1	-
Tanzania	36	19	5	1	3	1	-	4	3
Togo	3	-	-	1	-	-	-	-	2
Uganda	5	2	1	-	-	1	-	1	-
Zambia	21	7	2	2	2	2	-	5	1
Zimbabwe	36	25	-	2	2	3	1	1	2
Total (including S. Africa)	602	22	76	35	50	38	24	90	57
Total excluding (S. Africa)	430	202	45	24	29	32	7	53	38

(T = Total; AFF = Agriculture, Forestry & Fisheries; HN = Health & Nutrition; EGM = Energy, Geology & Mining; M = Manufacturing; E = Environment; BS = Basic Sciences; SHS = Social Human Sciences; M = Multidisciplinary)

Source: Updated from World Science Report (1998), International Research Centres.
Directory 1996-1998, and UNESCO Statistical Yearbook, 1998.

Annex 6: R&D Personnel in the National Research Centres in SSA, 1998*

Country	Total	R	SP	T	A	US
Angola	211	17	114	20	60	0
Benin	135	41	40	28	26	0
Botswana	367	62	31	122	122	0
Burkina Faso	1205	265	236	248	248	0
Burundi	2379	135	6	210	210	0
Cameroon	5110	655	578	1928	1928	0
Cape Verde	89	17	13	9	9	0
C. Afr. Republic	208	6	16	60	60	109
Congo	146	47	13	53	53	0
DRC	1183	141	112	256	256	535
Cote d'Ivoire	1546	219	75	112	112	127
Ethiopia	5553	2473	142	570	570	52
Gabon	43	4	0	11	11	5
Gambia	117	4	6	7	7	0
Ghana	5871	436	514	280	280	21
Guinea	114	50	10	5	5	49
Kenya	5832	797	692	656	656	464
Lesotho	24	10	5	0	0	0
Liberia	245	34	118	54	54	0
Madagascar	1012	178	84	607	607	0
Malawi	2293	185	210	344	344	568
Mali	358	74	46	57	57	0
Mozambique	599	21	53	29	29	309
Namibia	67	24	3	7	7	0
Niger	741	90	5	234	234	0
Nigeria	7913	937	1105	1991	3980	0
Rwanda	884	83	145	93	563	0
Senegal	1607	286	157	268	890	6
Seychelles	25	8	2	10	5	0
Sierra Leone	10	4	1	0	5	0
South Africa	16946	3799	1199	2678	4196	5074
Sudan	1565	83	100	882	500	0
Swaziland	219	32	15	73	84	15
Tanzania	6069	916	1212	703	3238	0
Togo	108	32	5	29	42	0
Uganda	566	136	107	64	259	0
Zambia	1861	315	186	470	853	37
Zimbabwe	4369	528	74	761	3006	0
Total (including S. Africa)	77590	13174	7330	13929	35786	7371
Total excluding (S. Africa)	60664	9375	6131	11251	31590	2297

(R = Researchers; SP = Support Professionals; T = Technicians; A = Auxilliary Staff; US = Unallocated Staff)

Source: Updated from World Science Report (1998), International Research Centres Directory, 1996-1998, and UNESCO Statistical Yearbook, 1999.

Annex 7: Total Number of African Professionals Admitted into the USA, 1982-1989

Country	1982	1983	1984	1985	1986	1987	1988	1989
Ethiopia	202	188	190	171	157	144	198	372
Cape Verde	27	25	23	24	25	23	26	2
Ghana	138	165	152	182	175	159	164	309
Kenya	162	192	212	196	201	203	207	261
Liberia	85	46	52	63	95	75	78	136
Siera Leone	47	44	47	55	45	59	55	96
Tanzania	110	94	128	102	102	121	103	156
Uganda	92	101	107	63	81	63	41	124
Nigeria	340	278	277	339	435	492	547	1015
Total Africa	2855	2569	2737	2864	3161	3331	353	4783
Total World	64740	58695	58842	62281	63373	54099	65202	90739
Africa as % of World	4.4	4.4	4.7	4.6	5	5.2	5.1	5.3
Ethiopia as % of Africa	7.1	7.3	6.9	6.0	5.0	4.3	5.9	7.8

Source: Adapted by Aredo, D (2000) "Human Capital Flight from Africa: An Assessment of Brain Drain in Ethiopia". Paper presented at the Regional Conference on Brain Drain and Capacity Building in Africa. Addis Ababa, Ethiopia, p.29.

Annex 8: Selected Case Studies on Technological Capacities in SSA

Zimbabwe

Zimbabwe has made tremendous progress in the evolution of specific capabilities in textiles, clothing and footwear industries. In garment and textiles production, manufacturers have developed design capabilities. Most mills have established technical development departments which keep a tab on market requirements, the need for new varieties and styles of fabric. Fashion enterprises acquired CAD/CAM capabilities. The productivity of many firms has improved steadily.

In the case of footwear, the Bata and Superior shoe companies acquired their own CAD facilities. Much of the equipment in shoe factories is old, but it is appropriate in that it is operational and is readily maintained with local skills. Compared to international standards, its productivity in units such as pairs per person per day is low. However, total costs of production (reflecting the written down costs of the antiquated, but operational equipment and relatively low labour costs), is competitive. However, footwear companies are also importing modern sophisticated equipment, to enable them compete on export markets and against imported footwear. Superior footwear produces for export, following installation of ultra-modern "link" system. A computer-based diagnostic and training system has been commissioned. Another company, Cathula, uses far less sophisticated machinery, producing high quality sandals. It has reacted to problems associated with a shortage of foreign currency by innovating.

The availability of skills is emerging as the limiting factor since importation of inputs is easy. To get suitable supervisory staff and skilled personnel for product design is very hard. Thus, local designers need to travel abroad and overseas designers to visit Zimbabwe. There is lack of formal training, but in-house training is evident. Bata has developed infrastructure so as to enable it offer various kinds of training programmes to its entire staff. In 1991, the British Council advanced scholarships to Zimbabweans so as to study leather technology in the UK. Bata has access to information through its international network.

Subcontracting is very much resisted in Zimbabwe, because the companies do not wish to be dependent on the performance of others to meet their won quality standards. There is also fear that subcontracting may lead to loss of market to subcontractors who would in time establish relations with the ultimate client, whether in the export or domestic market. The reluctance to subcontract is one of the many barriers to entry that a small producer is faced with in a market dominated by efficient enterprises. This aversion has had an influence on the evolution of capabilities.

Ivory Coast

This study by Kouassy and Bohoun (1995) examines three sectors: food processing and preservation (Capral-Nestle and Saco), cooking fats industry (Cosmivoire and Trituraf) and the textile industry (Uniwax and Cotivo).

Comivoire relies heavily on specialized companies to install equipment and train staff. This has entailed the payment of huge fees. There is very little evidence that they have a long-term plan to embark on training by in-house staff. This has compromized their potential for capability development.

Trituraf, on the other hand, secured technology through a route that made it easy for them to save costs. A firm by the name Rochet facilitated their access to technology markets affording them the technical experience, international contacts and links with European suppliers of machinery. This broadened their knowledge considerably. What is crucial, is that during the establishment of the production facilities, the local staff were heavily involved. This led to the build-up of experience and skills in the use of the machinery.

In the food processing area, Capral devoted considerable resources to investment. Capacity increases of the 1980s explain high acquisition of physical capital in the late 1980s. The company also devoted significant resources to foreign technical assistance. Capral, producing instant coffee under a Nestle license, pays heavy fees for that. The company needs regular technical assistance from the mother firm to carry out these activities for the selection, installation and maintenance of machinery, and the training of executives. Training of the employees is usually done on the job. Capral has limited opportunities as pertains to the marketing strategy. However, the fact that the company relies on the mother firm to select, install, and maintain machinery, is a clear illustration of their weakness to build capabilities inhouse.

Saco until 1985 had physical capital as the most important component of the total investment. Investment in trading and marketing activities have become much more important. Its investments are generally self-financed. It has been forced to find an appropriate technology and a method of strictly controlling the production and quality control process. It uses the "Dutch process", a set of free processes that are not subject to licenses and patents and which are widely known all over the world. It has installed a computerized device that provides the firm with day-to-day cost indicators and monthly reviews of the production units. A technical control unit has helped increase its flexibility, hence meeting various standards and specifications required by some markets. Management of human resources is also seen as a major priority by Saco. Professional training programmes were increased from 1990. The company's exports are destined to its production subsidiaries in Europe and the US, though some exports do reach Asia and Australia as well.

Uniways' major investment was in the 1980s despite its having excess capacity. New investments were centred not only on physical assets, but also rather on marketing and trading activities. Its cloth printing uses a simple wax-resistant technology. The technology is from Vlisco, one of the European partners, which has selected all the machines presently used by the firm. It takes very minimal technical innovation. Its lack of technical autonomy explains the high royalties and technical assistance fees paid by the firm, whereas training costs are low. Training is for technical competence of the staff, but not acquisition of new technologies. Its limited export possibilities lead to the six-fold increase in the advertising expenses between 1985 and 1990.

Cotivo's increased investment in 1987 was for the acquisition of physical capital. The firm's activities to export markets were both to counterbalance domestic market difficulties and to take advantage of an export subsidy scheme launched by the government. The investments were for new equipment for spinning, the largest items being the open-ended turbines and second-hand looms, and pre-cutting and trimming technologies. Its main supplier of the machinery and equipment was the German firm Sanfir.

Kenya

1. Utilization of professional and engineering skills in Kenya[21]

This is a review of Paul Bennel's paper[22]. Engineering manpower is very important in the development of indigenous technological capabilities (ITC) of less developed countries (LDCs), although research has hardly focused on the training and utilization of engineering skills. However, for the locally trained engineers (including non-Africans trained locally), brain drain has been the most viable manifestation of the extent to which international market for skills exists. Sometimes the outflow of the graduate engineers cannot be considered to be typical market-oriented brain drain. Consultancy enterprise is a key institution involved in selecting and modifying foreign technology that leads to development of technological self-reliance.

The concentration of most talented and experienced engineering manpower in this sector provides the basis for an indigenous capability to 'unpackage' foreign technology, thereby reaping considerable short-term advantages. The ability to utilize the engineering manpower leads to considerable cost saving by making greater use of raw materials, reducing reliance on proprietal technology and dispensing with the payment of often-substantial foreign consultancy fees. It also has several external economies like learning by doing, increasing the level of pre-investment information and faster diffusion of technology. There are six African consultancies and only one can be considered to be an attempt by non-citizen engineers to create an African front to satisfy the market. The consultancy sector is mainly civil engineer-oriented.

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21 No recent studies are available. However, to appreciate the pervasiveness of technological inadequacies in Kenya, consult Khalil, M. H. (1995) "Will Kenya Become an Industrialized Country in 15 Years?: An Extrapolation for Africa". ACES Working Paper, African Centre for Environmental Studies, Nairobi, Kenya; and Khalil, M. H. (1992) "The acquisition of technological capabilities in the power sector: the case of Olkaria Geothermal Plant in Kenya". Unpublished Ph.D. thesis, University of Sussex, Brighton, Sussex, U.K.

22 See Benell, P. (1984) "Utilization of professional and engineering skills in Kenya". In Technological Capability in the Third World, Fransman, M. and K. King (eds.). Macmillan Publishers, London, pp.

Manufacturing enterprises constitute a major source of demand for mechanical and electrical engineers in the private sector. However, the pattern of the import-substituting industrialization in Kenya has not generated sizeable demand for formally locally trained engineering manpower. Most technology is purchased outright from suppliers in the advanced industrial countries. They have attempted to suppress knowledge concerning its operations, maintenance and repair from local manpower. The principal constraint frustrating engineering manpower localization is the non-availability of local manpower processing, the requisite technical and more important managerial competence, which can only be acquired after several generations of appropriate socialization.

The acquisition of higher engineering qualification, enhances the trainability of an employee required to perform technical tasks. Formally trained engineering manpower recruitment having general skills, usually increases training costs to acquire the specific skills needed for operation. Given the simple labour hierarchy required to satisfy limited technical and managerial requirements, there is little need for the privilege of mental over manual labour in order to provide the basis for the stratification of the working class within an enterprise. The public sector has got higher-level manpower requirements that are much more intensive and continue to expand rapidly than the private sector. Public sector engineering pyramid is top-heavy with too few engineering technicians, compared with university trained engineers.

Civil engineers are mainly in central government ministries and the engineering consultancy sector and generally utilize a high level of their formally acquired knowledge in designing and supervising the construction of capital projects. Electrical engineers are mostly employed in the public sector. Mechanical engineers generally utilize only a small proportion of their formally acquired engineering knowledge and do not engage in design and/or research and development activities. They are mostly employed in private industrial sector. In conclusion, it is therefore among this group of engineers that the mismatch between the metropolitan, anglophonic conception of the professional engineer, which has formed the basis of training policy, and the subsequent utilization of this manpower, is most apparent. This is as a result of lack of liaison between the engineering faculty and the industrial sector. This has, however, led to the problems faced by young engineers in gaining full professional status through registration and increased underutilization. It has also led to open unemployment and may extend to the next decade.

2. *Indigenous technological capability: Kenyan textile and wood products*

This is a review of Steve Langdon's paper[23]. Enterprises usually organize the major inputs of essential technological knowledge for their own development, and without institutional reliance on foreign technology, are capable of confronting new product or process initiatives. If an enterprise is able to organize the technological knowledge for such initiatives, then it possesses indigenous technological capability (ITC) in its sector, otherwise it does not posses ITC. In Kenyan firms, there are three textiles and four wood enterprises that clearly show the characteristics of ITC. Prior technological dependence of about seven enterprises that grew on the basis of foreign technology inputs and continued to have institutional links with foreign technology suppliers, six are prepared to initiate new processes or products. The insignificance of formal research and development in shaping ITC is evident in the enterprises. Technological independence is likely to encourage firms to innovate; out of ten enterprises without present technology links abroad, nine were undertaking new product changes.

Several local firms relied on their own technological inputs and had no formal technology links abroad, but were undertaking product or process changes based on their own technological knowledge. The ITC firms were characterized by their family-owned basis and their small beginning. The ITC was developed through learning-by-doing from small beginnings and strengthened by direct managerial and technical experience overseas. The consequences of the gradual enterprise expansion, which is a factor contributing to growing ITC, was the unpackaged character of technological acquisition made by the firms; some combined second-hand machinery from overseas. Additional mechanisms by which enterprises built up their technological capacity directly, were through various direct forms of contact and experience abroad, which was rare, but through direct experiences with manufacturers overseas.

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23 Langdon, S. (1984): "Indigenous technological capability in Africa: the case of textiles and wood products in Kenya". In Technological Capability in the Third World, Fransman M. K. King (ed.). Macmillan Publishers, London, pp. 355-374.

The acquisition of ITC by the firms led to increases in average annual sales and after-tax profitability. Reliance on machinery and technology sold by parent company, made the enterprise to fail to achieve viability and became bankrupt, and was rescued by the state at a cost of some Kenya shillings 70 million. Thus, technological dependence on foreign enterprise had been then extremely costly in the textile industry. Employment effects of ITC firms have been greater than non-ITC firms. While levels of imported inputs in textiles are virtually identical, ITC firms have shown much greater propensity to initiate linkage effects with further indirect employment benefits. Acquisition of ITC by firms also led to high levels of capital accumulation, growth rates, investments and increased capacity of penetrating.

Overseas ownership by multinational corporations, precisely because it offers easy continuing access to technology from abroad, inhibits indigenous technological development. This powerful multinational corporation, presents impediments to ITC development. Several other factors seem to have evolved. These include pressures emanating from western European enterprises, based in turn on restructuring patterns affecting given industries there. Secondly, the efforts within developing countries which continues to move painlessly to export manufacturing rather than import substitution, has been a problem. Close relations that have developed between state personnel and foreign enterprises in Kenya and domestic political economy relations that affect the role allowed to certain local entrepreneurs, are also impediments to acquisition of ITC. All these suggest that movement towards ITC industrial strategy in Africa, though feasible, require major political shifts to make it likely. The growing economic crises across the continent of Africa, provides pressure towards such a movement, but the international and domestic forces threatened by this, are powerful and effective, and change will not come easily.

Tanzania

This article by Bagachwa and Mbelle (1995) shows that the textile firms in Tanzania have not been able to build investment capabilities. Four firms are covered by the writers, namely, NEM, Themi, Afrocooling and Matsushita. In general, firms in Tanzania usually lack skills needed to:

- Identify and evaluate the projects.
- Specify the appropriate and current location, scale, and product and input mixes.
- Research, select, bargain, purchase and transfer the appropriate technology.
- Participate in carrying out basic and detailed engineering functions, like equipment specification, procurement and testing, civil construction, mechanical erection and commissioning, and to execute the start-up and training functions.

It may be possible to acquire skills from specialized engineering or consulting companies from developed countries, but the cost may be unbearable. Lack of active participation in the design and execution of certain critical investment functions, have led to inappropriate technology choices and failure to master, adapt and improve upon imported technologies or failure to establish linkages with the suppliers.

Northern Electrical Manufacturing firm (NEM) entrepreneurs missed the chance to participate in and learn from key initial entrepreneurial tasks. Themi's entrepreneurs were brought into a ready-made project. They were responsible for the procurement of machinery and installation. Investment capability was possible, because three of the entrepreneurs, though not very experienced, held a degree in engineering. Themi's entrepreneurs made choices from various equipment suppliers, enabling them to negotiate for the best terms.

Unlike NEM and Themi, Afrocooling had to undergo the long and difficult, but worthwhile process of initiation into feasibility studies preparation, project identification and execution. Entrepreneurs hired consultants from India to install the plant considered as appropriate to the Tanzanian, given the firm's flexible, small scale, and labour-intensive operations. Matsushita Electric Industries of Japan was involved in this. In the 1960s, there was no sufficient engineering capacity. Generally, the firm's current management is not knowledgeable of what transpired at the crucial early stages, except for the canvas which still has a foreign contract.

The major source of production capabilities has been the accumulation of entrepreneurial, technical and managerial skills from previous experience in commerce and industry. It follows that export competitiveness and industrial performance are

usually very weak in cases where such experience is absent. Training has been another source of production capability. Foreign technical assistance is also very important. Firm-level training was bound to be limited as private firms feared losing their trainees once they are sufficiently qualified. Flexible and adaptive capabilities were also built. These were crucial since they enabled enterprises to cope with rapidly changing global market conditions and technological developments.

Africooling has managed to establish significant linkages through its sales of radiators to the local automobile industry, including vehicle-assembling firms. Themi does not have subcontracting activities with other industrial firms, but has forged some forward linkages with the agricultural sector via sales of ploughs and ox-carts. Limited backward linkages have been created by Matshusita in conjunction with Kibo Paper Industries and Tanzania Efelets. The absence of significant inter-sectoral linkages can be explained by poor infrastructural facilities for small firms, biases in policies and credit markets,
and the lack of an extension network. The pattern of import substitution has led to import-dependent assembly. Furthermore, the ease of access to donor funding has discouraged producers from actively looking for locally available parts and materials. It may also reflect on the management's inability to search for, or appreciate the positive role which can be played by subcontracting.

Mauritius

Human resource development has contributed significantly to production capabilities in Mauritius. Clerical staff have generally had a broad-based education with the majority having passed their advanced level examinations. Managerial staff hold diploma or degree and production workers have received some form of technical training. Firms pursue in-house or on-the-job training for factory workers, formal outside training for certain categories of personnel, overseas courses or tours of factories. Firms would recruit on the local market or from their existing staff. Aggressive advertising is used to attract workers. Poaching of workers, especially skilled personnel, is also common. Remuneration is made up of basic wages, fringe benefits, and attendance and productivity bonuses. Wages and conditions of employment are subject to extensive government regulations.

Production processes for chemical fertilizer, refined oil and paint, are capital intensive. There has been little change in the case of fertilizer firms in the technology used since its creation. With growing labour scarcity and the increase in salaries, the paint manufacturer has installed more powerful equipment. New technologies are obtained from visits to overseas suppliers or trade fairs and the firm has invested substantially in Research and Development — to improve quality and develop new types of product. The demand approximately matches capacity for the chemical fertilizer manufacturer.

The oil firm has targeted the Preferential Trade Area (PTA) markets. All firms occasionally use consultant services, mostly to meet their training needs. These services are crucial for the survival of the firms. Only the jewelry firm has a licensing agreement with its French partners. It also has a management agreement with them. Management agreements with foreign partners are directly related to the level of foreign participation in shareholding. Joint ventures are important because they facilitate access to technology, material inputs and markets. They also increase the competitiveness of the enterprises. With the introduction of new technologies, new firms would be expected to rely heavily in the procurement of technical services unless they have their own technical expertise. Only edible oil and knitwear enterprises have so far made use of contracted technical services for maintenance of computers. Most export-oriented enterprises and import substitution enterprises maintain links with their suppliers of equipment — to keep up with new types of technologies coming on the market and to evaluate their usefulness. The links are also maintained to ensure that after-sales service and maintenance are provided.

It should be noted that most technological capacities that have developed in Africa have, in general, not been products of policy stimulus or conscious governmental strategies. If governmental influence was at play, it was for the most part incidental. Some African governments entered into agreements with overseas companies to invest in telecommunications, energy, and other sectors. In nearly all investments, overseas firms have been in control from pre-investment phases to the final stages of commissioning. What African governments did was to emphasize on training to enable locals run and operate the new facilities. These were the only production capacities that governments had a direct bearing on. However, most African administrators had not been active in guiding both local and overseas players in evolving investment and innovation capabilities in areas where opportunities prevailed or when prospects for enhancing domestic content could be explored to the economy's advantage. If significant capacities did evolve in particular cases, the source of that stimulus could be traced to factors more internal to a firm, e.g. the local manager or immediate external pressures such as supply constraints or innovation-inducing bottlenecks. Clearly, rarely have African governments forged dynamic mechanisms (with teams to implement) consciously designed to develop significant capacities beyond the production capabilities.

Investment negotiations, domestic content and technological capacities in SSA: the case of the Kenya transmission project

Sub-Saharan African countries have rarely taken technology negotiations with the seriousness they deserve. This general attitude is best captured by the case of the Kenya Transmission Project. In 1979, a bilateral agreement was signed between the Canadian Government and the Republic of Kenya to implement the Kenya Interconnector Project.

The agencies for the respective countries were the Canadian International Development Agency (CIDA) and Kenya Power and Lighting Company Limited (KPLC). According to the loan agreement, CIDA was to provide consulting, professional, technical and other services for the project. The contract package was dictated by CIDA and contained the following ingredients:

(a) Canadian content was to be maximized.
(b) The executing agency, Acres, was to ensure maximum opportunity to Canadian firms in bidding for work.
(c) Acres was to be responsible for evaluation, recommendation, and the placing of orders directly on KPLC's behalf, though the latter was to undertake some placing of orders themselves. Specific design and project management services were the responsibilities of Acres, and were carried out from their Toronto base. Management and supervision were coordinated through a Nairobi office.

The Interconnector Project, as it came to be known, comprised of a 220kV Kamburu-Mombasa transmission line and concepts for the project were ideas developed by Merz and Mclellan in the later seventies. KPLC was to provide inputs to detailed design, and the construction management role was to be provided by Acres.

During the project implementation phase, KPLC assigned a coordinator to liaise with Acres and various engineering and financial departments of KPLC. Acres cashed in on the large body of services which were not costed, and thus KPLC offered more than their fare share in the balance of responsibilities.

Kenyan participation comprised field supervision and commissioning, with constant consultations between KPLC and Acres. During the design specification phase, Acres relied heavily on KPLC for advice. The Acres field staff held meetings and discussed a number of field problems with KPLC Technical Manager and Company engineers. Clarifications usually centred on terrain aspects of the project and detailed engineering parameters.

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