National Technology Systems for Manufacturing in Sub-Saharan Africa *

Sanjaya Lall • Professor of Development Economics,
Queen Elizabeth House, University of Oxford, UK
sanjaya.lall@economics.oxford.ac.uk

Carlo Pietrobelli * • Professor of Economics Law School,
University of Rome III
c.pietrobelli@uniroma3.it

* Corresponding Author

ABSTRACT

There is an increasing concern about national 'competitiveness' among policy-makers in many countries. Equally shared is the agreement on the importance of industrial and, most of all, technological dynamism for competitiveness.

In developing countries industrial and technological performance is closely linked to their capacity to use technologies efficiently. This reflects the fact that they are seldom 'innovators' in a narrow sense, but they crucially need to be able to acquire the foreign technologies relevant to their competitiveness, absorb them, adapt and improve them constantly as conditions change.

Following this notion of innovation and technical change, we develop a concept of National Technology System, that builds upon, but differs in important respects, from the concept of National Innovation Systems. This paper contributes to this debate by specifically focusing on Sub-Saharan Africa (SSA). In this region, competitiveness is worsening, and deficiencies in the science and technological infrastructure seriously constrain industrial performance.

The paper uses detailed and original microeconomic evidence on scientific and technological infrastructure in support to industry in a sample of Sub-Saharan African countries, to conclude that, in spite of continuing liberalization and openness, this represents a fundamental weakness for African industry.

J.E.L. Classification. O14, O33, O34

Key words: Technology, Innovation, National Innovation Systems, Technology Transfer, Sub-Saharan Africa.

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1. INTRODUCTION

'National technology systems' are the developing world's counterpart to the 'national innovation systems' in industrialized countries, the discussion of which is now a major element in the literature on technology policy there. The idea that innovation occurs in a 'system' – a set of interacting enterprises, institutions, research bodies and policy makers that engage in technological activity, share in knowledge spillovers and often engage in collective action – is now widely accepted.[1] The evolutionary literature, in particular, stresses the uncertain nature of the innovative process and the central importance of continuous interactions between agents (Nelson, 1993). These interactions are systemic in the sense that the same elements recur in all economies and have a coherent set of predictable interactions. Thus, an analysis of the system and the strengths and weaknesses of its elements can by useful to policy makers.

Most developing countries do not create new technologies and so do not have 'innovation systems', in the usual sense of creating new knowledge at the frontier. However, they do have national systems within which they import, absorb, adapt and improve upon new technologies. Such technological effort is vital to their growth and competitive success, and it has systemic elements similar to those of innovation systems in advanced countries. While all such systems pertaining to knowledge creation and diffusion suffer from market failures, technology systems in developing countries are more likely to be prone to such failures in that markets and supporting institutions are less developed and information networks more confined. Moreover, technology systems in poor countries are set in trade and industrial policy regimes that are quite different from those in rich countries.

It is important to note, however, that technology development in industrial latecomers is not a trivial or automatic process. Even countries that import all their technology have to undertake significant, costly and risky effort to use the technology efficiently (section 3).[2] This needs an efficient technology system that is able to offset some of the inherent market and institutional weaknesses in these countries. It is thus important for development policy to analyse the features and constraints of these technology systems. It is more important for the least industrialised countries that tend to suffer the greatest competitive weaknesses and consequently find themselves facing the most severe problems as the open their economies to global competition

This paper analyses technology systems in five countries in Sub-Saharan Africa (SSA). These countries are at different levels of industrial development and so illustrate different sets of institutional problems. Ghana and Uganda are among the earliest liberalisers in the region, th4e former with an established industrial sector and the latter with a very small one. Zimbabwe is the most industrialised country in the region after South Africa (at least until its recent problems). Kenya is the next most industrially developed country in East Africa, while Tanzania is one of the weakest. Section 2 provides some background on the region.

1 Of the large and growing literature on this subject see Freeman (1997), Lundvall (1992), Metcalfe (1995), Nelson (1993), Edquist (1997) and Edquist and McKelvey (2000).

2 See, for instance, Lall (2001), Pietrobelli (1997) and UNIDO (2002).

TABLE 1: MANUFACTURED EXPORTS BY SSA AND SELECTED DEVELOPING COUNTRIES ($ MILLION)

	1980/81					1996/97				
	TOTAL	RB	LT	MT	HT	TOTAL	RB	LT	MT	HT
Kenya	706.7	606.0	58.0	31.0	11.8	913.1	519.5	257.0	103.5	33.2
Tanzania	56.7	38.4	14.5	1.9	1.9	99.1	71.1	19.1	2.2	6.7
Uganda	12.0	9.9	0.1	1.8	0.2	29.4	5.1	12.7	9.0	2.6
Ghana	144.3	135.4	3.0	2.6	3.2	N/A	N/A	N/A	N/A	N/A
Zimbabwe '85 & '98	360.5	97.2	84.4	173.6	5.3	873.6	336.7	229.2	290.3	17.4
South Africa	6 490.4	4 059.6	1 096.0	1 224.3	110.5	15 907.7	7 930.2	2 730.8	4 294.2	952.5
India	4 901.9	1 431.3	2 489.9	779.5	201.1	27 178.4	8 201.1	13 227.5	3 956.2	1 793.6
China	N/A	N/A	N/A	N/A	N/A	164 209.3	17 979.6	84 998.2	32 593.3	28 638.1
Korea	16 314.5	2 156.7	8 124.0	4 286.8	1 746.9	126 053.3	13 798.7	25 568.9	49 111.0	37 574.8
Malaysia	6 121.3	3 943.5	432.0	462.8	1 283.0	68 995.2	12 393.9	7 693.0	13 718.3	35 189.9
Thailand	2 258.4	944.5	709.7	564.6	39.7	47 190.4	9 127.9	11 961.5	9 662.8	16 438.2
Distribution (%)										
Kenya	100	85.8	8.2	4.4	1.7	100	56.9	28.1	11.3	3.6
Tanzania	100	67.7	25.7	3.3	3.3	100	71.7	19.3	2.2	6.8
Uganda	100	82.7	1.1	14.7	1.6	100	17,3	43,2	30,6	8,8
Ghana	100	93.9	2.0	1.8	2.2	N/A	N/A	N/A	N/A	N/A
Zimbabwe '85 & '98	100	27.0	23.4	48.1	1.5	100	38.5	26.2	33.2	2.0
South Africa	100	62.5	16.9	18.9	1.7	100	49.9	17.2	27.0	6.0
India	100	29.2	50.8	15.9	4.1	100	30.2	48.7	14.6	6.6
China	N/A	N/A	N/A	N/A	N/A	100	10.9	51.8	19.8	17.4
Korea	100	13.2	49.8	26.3	10.7	100	10.9	20.3	39.0	29.8
Malaysia	100	64.4	7.1	7.6	21.0	100	18.0	11.2	19.9	51.0
Thailand	100	41.8	31.4	25.0	1.8	100	19.3	25.3	20.5	34.8
Memo item: distribution by regions (%)										
World	100	25.4	18.8	41.9	13.9	100	18.4	18.6	39.0	24.1
Industrialised	100	22.6	17.8	44.6	15.0	100	17.2	16.1	43.0	23.7
All Developing	100	40.9	32.5	17.0	9.5	100	17.8	27.6	25.7	28.9
SSA*	100	89.3	6.3	3.0	1.4	100	40.8	44.2	13.0	1.9
East Asia	100	30.5	37.7	19.1	12.8	100	13.1	28.2	23.9	34.7
Latin America	100	71.9	15.6	10.2	2.2	100	27.6	18.7	37.3	16.5

SOURCE:. CALCULATED FROM COMTRADE DATABASE, AND NATIONAL SOURCES FOR UGANDA. * SSA EXCLUDING SOUTH AFRICA BUT INCLUDING MAURITIUS.

2. BACKGROUND

The poor industrial performance of SSA is well known. Much of the industrial sector has been state-owned, oriented to the local market and technologically backward. Despite liberalization and a cheap labour force (now probably among the lowest paid in the world), it has failed to build a competitive edge in export markets. It has attracted very little of the export-oriented foreign direct investment that has driven the growth of many East Asian economies. Mauritius is the major exception, apart from some recent (fairly small) investment in apparel production for the US market taking advantage of quota and tariff privileges offered by the African Growth Opportunities Act (AGOA). The long term impact of AGOA is not clear; it is possible that the investors, mainly from East Asia, will leave when the trade privileges end in 2008.

World trade has shifted from resource-based to medium and high technology-based products (Lall, 2001). However, SSA is not sharing in this trend. With the exception of South Africa and Mauritius, SSA has not altered its traditional specialisation in unprocessed primary products, the slowest growing segment of world trade and also the one that offers least by way of technological learning, skill creation and beneficial externalities. Tables 1 and 2 show manufactured export performance by the case study countries and selected comparators.

TABLE 2: MANUFACTURING VALUE ADDED IN SELECTED SSA COUNTRIES AND COMPARATORS

	Share of MVA in GDP (%)		MVA value (US$ m.)		Growth (%)	MVA per capita (US$)		Growth (%)	Equipment % MVA	
	1980	1996	1980	1996	1980-96	1980	1996	1980-96	1980	1995
Kenya	13	10	796	840	0.3	46.8	31.1	-2.5	15	10
Tanzania	11	7	555	334	-3.1	29.2	11.1	-5.9	8	6
Uganda	4	8	53	359	12.7	4.1	18.0	9.7	...	...
Ghana	8	9	347	594	3.4	31.5	33.0	0.3	2	2
Zimbabwe	25	19	1 248	1 260	0.1	178.3	114.5	-2.7	8	9
South Africa	23	24	16 607	28 389	3.4	572.7	747.1	1.7	21	20
India	18	20	27 422	57 942	4.8	39.9	61.3	2.7	25	25
China	41	38	81 836	262 657	7.6	83.4	216.2	6.1	22	25
Korea	29	26	18 260	122 407	12.6	480.5	1 912.6	9.0	17	38
Malaysia	21	34	5 054	27 728	11.2	361.0	1 320.4	8.4	20	40
Thailand	22	29	6 960	47 963	12.8	148.1	799.4	11.1	9	15

SOURCES: WORLD BANK, WORLD DEVELOPMENT INDICATORS 1998, WASHINGTON DC, UNIDO, INDUSTRIAL DEVELOPMENT GLOBAL REPORT 1997, VIENNA.

3. NATIONAL TECHNOLOGY SYSTEMS AND DEVELOPING COUNTRIES

This section deals briefly with analytical setting for this discussion. Much of the conventional development literature assumes away the need for capabilities as a distinct input into industrial development. It assumes that developing countries can choose and import technologies from advanced countries and use them in production at 'best practice' levels without further effort, cost or risk. If technology were transferable like a physical product (that is, if they were fully embodied in equipment, patents and blueprints), then indeed no further learning or capabilities would be called for – getting prices right would ensure that developing countries optimised their technological choice and use. Industrial capacity (physical plant) would be the same as industrial capabilities.

A large body of empirical research on developing countries suggests that this depiction is over-simplified and often misleading (Lall, 1992, Pietrobelli, 1997). Based on the evolutionary theories of Nelson and Winter (1982), it argues that firms do not operate on a typical neoclassical production function. There is no well defined and complete set of alternative techniques of which they have full and clear knowledge. Finding suitable technology at the right price involves cost and risk. Using it technology efficiently involves further cost and effort: search, experimentation, induction of new information and learning. Adapting the technology to different scales, new input and skill conditions and different product demands involves further effort. Keeping up with technical change is another set of demands on local learning. Technologies have large 'tacit' elements that have to be mastered by the recipient and cannot be sold by the technology supplier like a physical product. Without additional effort to learn different aspects of the technology, no enterprise can reach best practice levels of efficiency; in a liberalising world, this is the level needed for enterprises to survive and grow.

As technologies grow more complex and involve new skills and larger scales of production, formal research and development (R&D) often becomes necessary to monitor, understand and absorb it. Much of enterprise R&D, even in developed countries, is to keep track of, copy and adapt innovations from outside the firm (Cohen and Levinthal, 1989). In developing countries, the main function of R&D is to master, adapt and improve imported technologies; only at some relatively mature stage does it become truly innovative.

The way in which knowledge is used differs by level of development. In mature industrial countries, the competitive use of technology is largely a matter of innovation – the ability to create new products and processes. In developing countries, it is more a matter of building the ability to use existing technologies at competitive levels of cost and quality. How difficult this is and how long it takes depends on the country and the technology, but learning is always necessary. Even routine capabilities, say for quality or process optimisation, take years to build in industrial newcomers. More advanced capabilities, for modifying, improving or generating technologies, can take longer to build. The pattern of industrial success in the developing world reflects to a large extent by the effectiveness with which countries have undertaken learning (Lall, 1996, Pietrobelli, 1998). Some have reached the frontiers of advanced technologies, others, as in Africa, have not been able to build even the basic operational capabilities needed to compete internationally in simple technologies.

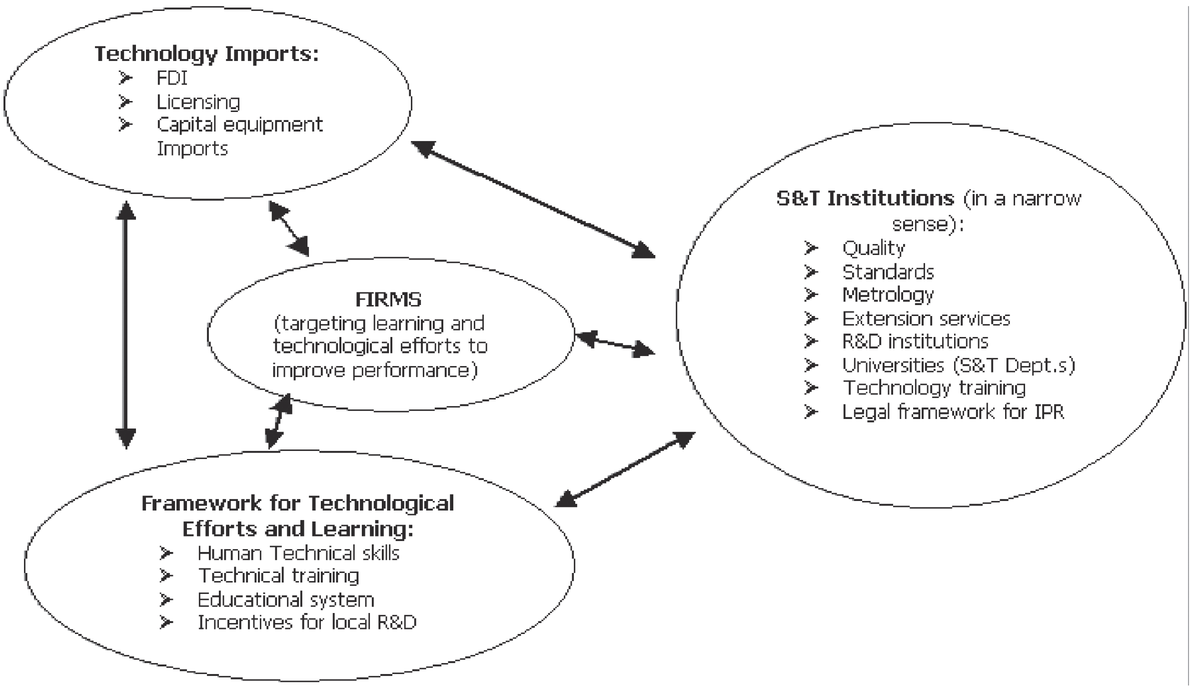
The rise of globalised production under the aegis of TNCs reduces to some extent the need for building domestic capabilities. TNCs provide affiliates with intangible assets (skills, technology, production expertise, training and so on), so that the host economy needs to offer correspondingly less 'ready-made' capabilities and invest less in subsequent absorption. Considerable industrial and export growth has taken place on this basis in countries with relatively low local technological capabilities. The growth of global production systems does not, however, do away with the need for (complementary) local capabilities (Guerrieri et al., 2001). In later stages as more advanced technologies have to be deployed and more efficient local suppliers needed, there is again a need for local capabilities.

Firms do not learn or innovate on their own but in intense interaction with other firms, factor markets, support institutions, and governments. They respond to rules on trade, competition, employment, intellectual property or the environment, and they behave in ways fashioned by their history, culture and environment. The interaction of economic, social and political factors provides the system within which firms learn and innovate, and so compete in global markets. As noted, such systemic factors also apply to developing countries, where technological effort is embedded in the specific economic, policy and institutional context of each country.

Our focus here is on two aspects of national technology systems: technology policies in the narrow sense and technology institutions. Technology policies cover such areas as technology import by licensing and FDI, incentives for local R&D and for training. Technology institutions refer to bodies such as quality, standards, metrology, technical extension, R&D and technology training. They may be government run, started by the government but run autonomously, or started and managed by industry associations or private interests.

Many services provided by these institutions are the essential 'public goods' of technological effort, difficult to price in market terms. Public research institutes and universities undertake basic research that does not yield commercial results in the short term, but provides the long-term base of knowledge for enterprise effort. Quality, standards and metrology institutions provide the basic framework for firms to communicate on technology and keep the basic measurement standards to which industry can refer. Extension services help overcome the informational, technical, equipment and other handicaps that SMEs tend to suffer. The provision of these services faces market failures of the sort that every government, regardless of its level of development, has to remedy.

Diagram 1: A Developing Country's National Technology System



4. TECHNOLOGY IMPORTS

The main forms in which technologies are imported formally are capital goods, licensing agreements and foreign direct investment. There are, of course, also many informal forms of technology import like copying, migration, trade fairs, journals and the like, but these are difficult to measure and so are not considered here.

TABLE 3: RECENT EQUIPMENT IMPORTS FROM SELECTED SSA COUNTRIES AND COMPARATORS (US$ MILLIONS AND PERCENTAGES)

Country	Year	Non-electrical equipment	Electronic & electrical equipment	Total equipment imports	Total Imports	Equipment as % of total imports	Machinery imports per capita ($)	Electronics imports per capita ($)	Total equipment imports per capita ($)
Kenya	1998	427.8	218.9	646.7	3,301.8	19.6	23.8	12.2	35.9
Tanzania	1998	215.4	69.1	284.5	1,416.3	20.1	8.0	2.6	10.5
Uganda	1988	76.6	14.5	91.1	907.0	10.0	2.6	0.5	3.
Ghana	1992	367.0	98.4	465.4	2,145.4	21.7	18.4	4.9	23.3
Zimbabwe	1998	641.5	240.1	881.6	3,157.8	27.9	16.9	6.3	23.2
South Africa	1998	4,884.0	4,343.2	9,227.2	26,624.1	34.7	444.0	394.8	838.8
India	1998	4,674.1	2,252.8	6,926.9	42,491.9	16.3	4.9	2.4	7.3
China	1998	24,371.8	27,821.8	52,193.6	140,236.8	37.2	20.1	22.9	43.0
Korea	1998	11,000.5	19,147.2	30,147.7	93,280.9	32.3	171.9	299.2	471.1
Malaysia	1998	9,700.6	24,375.8	34,076.5	57,759.4	59.0	461.9	1,160.8	1,622.7
Thailand	1998	8,562.4	9,100.4	17,662.8	42,684.1	41.4	142.7	151.7	294.4

SOURCE: UNITED NATIONS COMTRADE DATABASE.

Capital goods imports: The five countries import relatively embodied technology in the form of new capital goods, either as a share of total imports or on a per capita basis (Table 3). The only other developing country in the table that imports less is India, which still had a relatively highly protected capital goods industry. East Asia largely relies on capital equipment imports. The low level of equipment imports into the African countries may seem surprising in view of the fact that none of them now imposes any restrictions on such imports, imposes low or zero tariffs on equipment and has subjected enterprises to import competition. The slack suggests not the lack of a suitable incentive framework for technology upgrading but the absence of capabilities to use new technologies at competitive levels. In other words, firms invest little in new embodied technology because they realise that they do not have, and cannot build in a reasonable period, the capabilities needed to use it in open markets.

Foreign direct investment: FDI is one of the most important sources of technology transfer to many developing countries, and its importance is rising with the globalisation of production. Tables 4 and 5 show FDI inflows by region and into African countries. There has been a gradual increase in inflows into SSA but the region's shares remain very small. As noted below, FDI in Africa is also highly concentrated in a few resource rich countries (South Africa, Angola and Nigeria) and, apart from South Africa, relatively little goes into manufacturing.

TABLE 4: FDI INFLOWS, 1988-2001

	INFLOWS (US$ m)		INFLOWS (shares)	
	1988-93 ann. average	2001	1988-93	2001
World	190 629	735 146	100.0	100,0
Developed countries	140 088	503 144	73.5	68.4
Developing countries	46 919	204 801	24.6	27.9
North Africa	1 388	5 323	0.7	0.7
Sub-Saharan Africa	2 084	11 841	1.1	1.6
Latin America, Caribbean	13 136	85 373	6.9	11.6
South and East Asia	27 113	94 365	14.2	12.8
Least Developed (43)	1 361	3 838	0.7	0.5
African LDCs	822	3 798	0.4	0.3

SOURCE: UNCTAD, WORLD INVESTMENT REPORT 2002.

Of the five case study countries, Uganda has the largest recent value of and increase in FDI, followed by Tanzania and Zimbabwe (though the latter is down from 1991-94). Uganda has relied increasingly on this channel of technology transfer, to become one of the largest recipients (in relative terms) in Africa. UNCTAD qualified it as a 'frontrunner' among African countries in attracting FDI in 1992-96, along with Botswana, Equatorial Guinea, Ghana, Mozambique, Namibia and Tunisia (UNCTAD, 1998). Ghana suffers a decline after a rise in the earlier period. The average value of inflows during 1995-98 varies between a high for $138 million for Tanzania and a low of $26 for Kenya.

What do the inflows signify for technology inflows? Unfortunately not very much, in that much of the FDI is "either in the primary sector, particularly petroleum, or in infrastructure. And, with the exception of South Africa, other SSA countries have seen very little inflows in the manufacturing sector in recent years" (Pigato, 1999, emphasis added). While FDI into primary and infrastructure activities is desirable and economically beneficial, in terms of transfer of technology it does not add much to industrial capabilities or efficiency.

TABLE 5: FDI INFLOWS INTO SUB-SAHARAN AFRICAN COUNTRIES, 1987-1998 (PERIOD AVERAGES AND CHANGES ON PREVIOUS PERIOD, $ MILLION)

	Period Averages			Changes		
Country	1987-1990	1991-1994	1995-1998	1987-1990	1991-1994	1995-1998
Sub-Saharan Africa	1455	1807	5583	385	352	3776
Angola	29	395	570	-285	367	175
Benin	1	8	10	1	6	3
Botswana	73	-87	89	20	-160	176
Burkina Faso	4	16	36	3	12	20
Burundi	1	1	2	0	-1	2
Cameroon	2	148	102	-112	146	-46
Cape Verde	1	1	21	1	0	19
Central African Republic	3	-8	-1	-3	-11	7
Chad	7	11	14	-16	4	3
Comoros	4	0	1	4	-3	0
Congo, Democratic Rep. of	0	0	0	0	0	0
Congo, Republic of	-2	131	361	-34	133	231
Côte d'Ivoire	51	20	255	12	-32	235
Djibouti	0	2	3	0	2	1
Equatorial Guinea	2	22	314	6	20	292
Eritrea	..	0	26	..	..	26
Ethiopia	0	0	0	0	0	0
Gabon	66	-113	-95	5	-179	18
Gambia, The	7	9	8	6	2	-1
Ghana	10	100	92	6	90	-9
Guinea	15	70	52	13	55	-18
Guinea-Bissau	0	0	0	0	0	0
Kenya	40	8	26	16	-32	19
Lesotho	14	11	148	11	-3	137
Liberia	10	..	..	-4	..	..
Madagascar	9	14	16	9	5	2
Malawi	0	0	22	-1	0	22
Mali	3	4	42	1	0	39
Mauritania	3	8	1	-2	4	-7
Mauritius	29	-2	31	24	-32	33
Mozambique	6	29	99	-33	23	70
Namibia	7	85	127	7	78	42
Niger	16	0	0	13	-16	0
Nigeria	865	618	984	557	-248	366
Rwanda	15	4	3	1	-12	0
Sao Tome and Principe	0	2	2	0	2	0
Senegal	24	20	104	31	-4	85
Seychelles	21	7	45	10	-14	38
Sierra Leone	18	11	14	59	-7	3
Somalia	0	..	..	6	..	..
South Africa	-81	124	1528	-82	205	1404
Sudan	1	..	..	-1	..	..
Swaziland	51	38	19	41	-13	-18
Tanzania	0	37	138	0	37	101
Togo	12	10	12	8	-2	2
Uganda	0	3	116	0	3	113
Zambia	134	10	160	103	-124	150
Zimbabwe	-18	44	85	-19	62	42

SOURCE: PIGATO (1999) BASED ON IMF AND WORLD BANK STAFF ESTIMATES

Technology licensing: As far as licence payments are concerned, patchy data from UNCTAD show that SSA excluding South Africa paid US$84 million in 1997 for imported technology, a tiny 1.5 percent of the amount spent by the developing world. Of this amount, Kenya accounted for US$39 million and Swaziland for another $39 million, and South Africa alone spent US$258 million. In the same year, by comparison, Thailand spent US$813 million, India US$150 million and China US$543 million. Thus, licensing is clearly not a major channel of foreign technology inflow into SSA.

5. THE SKILL BASE

Skills in general, and technical skills in particular, are the base on which technological capabilities are built. With the rapid pace of technical change, the spread of information technologies and intensifying global competition, skill needs are growing and changing (Lall, 1999). While it is not possible to capture the complex nature of the skill base with national data, table 6 shows two available measures. They are enrolments at the tertiary level in all subjects and in technical subjects (science, mathematics and computing, and engineering). Enrolment data are not optimal for assessing the national skill base,[3] but they are the only data available on a comparative basis.

Table 6: Tertiary enrolments in total and technical subjects, 1995

	3 level enrolment		Technical Enrolments at 3 level							
	No. students thousands	% of Population	Natural Science numbers	%	Math's, computing numbers	%	Engineering numbers	%	Total Tech. Subjects numbers	%
Sub-Saharan Africa										
Ghana	9 600	0.055	1 200	0.007	200	0.001	700	0.004	2 100	0.012
Kenya	31 300	0.115	3 600	0.013			1 000	0.004	4 600	0.017
Tanzania	12 800	0.043	800	0.003	100	0.000	2 700	0.009	3 600	0.012
Uganda	27 600	0.140	800	0.004	300	0.002	1 500	0.008	2 600	0.013
Zimbabwe	45 600	0.408	2 200	0.020	800	0.007	6 700	0.060	9 700	0.087
South Africa	617 900	1.490	21 700	0.052	30,500	0.074	20 000	0.048	72 200	0.174
Sub-Saharan Africa	1 542 700	0.28	111 500	0.02	39 330	0.01	69 830	0.01	220 660	0.04
Comparators										
Developing countries	35 345 800	0.82	2 046 566	0.05	780 930	0.02	4 194 433	0.10	7 021 929	0.16
Argentina	1 069 600	3.076	69 700	0.200			92 600	0.266	162 300	0.467
Chile	367 100	2.583	8 800	0.062			94 300	0.664	103 100	0.726
India	5 582 300	0.601	869 100	0.094			216 800	0.023	1 085 900	0.117
Korea	2 225 100	4.955	163 700	0.365		0.000	577 400	1.286	741 100	1.650
Taiwan	625 000	2.910	16 800	0.078	32,800	0.153	179 100	0.834	228 700	1.065
Malaysia	191 300	0.950	8 800	0.044	4,600	0.023	12 700	0.063	26 100	0.130
Sri Lanka	63 700	0.355	8 100	0.045	300	0.002	6 800	0.038	15 200	0.085
Developed countries	33 774 800	4.06	1 509 334	0.18	1 053 913	0.13	3 191 172	0.38	5 754 419	0.69

SOURCE: UNESCO (1997), NATIONAL SOURCES.

3 Data on educational enrolments may be misleading because they do not take account of the quality (and drop-out rates) of the education or its relevance for local industry.

The dispersion in skill creation is much wider for technical subjects than for general enrolments. The leading 3 countries in terms of total technical enrolments – China (18%), India (16%) and Korea (11%) – account for 44 percent of the developing world's technical enrolments, the top ten for 76 percent. SSA, with about 12 percent of the developing world population, accounts for 4.4 per cent of its total tertiary, 3.1 per cent of technical tertiary, and 1.7 per cent of engineering, enrolments. The total number of engineers enrolled in the whole of SSA (about 70,000) is only 12 per cent of the numbers enrolled in Korea (577,000).

6. TECHNOLOGICAL EFFORT

Technological effort is essential to building capabilities. Much of the effort is informal, and is impossible to measure and compare across countries. What is available and used commonly for this purpose is formal R&D. There is some justification for using this measure: R&D become important for technology absorption and adaptation in industrializing countries, even if they do not innovate as they industrialize. This is also true at the enterprise level, where a substantial part of R&D is for monitoring and absorption rather than frontier innovation (Cohen and Levinthal, 1995).

TABLE 7: R&D PROPENSITIES AND MANPOWER IN MAJOR COUNTRY GROUPS (SIMPLE AVERAGES, LATEST YEAR AVAILABLE)

Countries and regions (a)	Scientists/engineers in R&D		Total R&D	Sector of performance (%)		Source of Financing (% distribution)		Source of financing (% of GNP)	
	Per mill. population	Numbers	(% of GNP)	Productive sector	Higher education	Productive enterprises	Government	Productive enterprises	Productive sector
Industrialised market economies (b)	**1 102**	**2 704 205**	**1.94**	**53.7**	**22.9**	**53.5**	**38.0**	**1.037**	**1.043**
Developing economies (c)	**514**	**1 034 333**	**0.39**	**13.7**	**22.2**	**10.5**	**55.0**	**0.041**	**0.054**
Sub-Saharan Africa (exc. S Africa)	83	3 193	0.28	0.0	38.7	0.6	60.9	0.002	0.000
North Africa	423	29 675	0.40	N/A	N/A	N/A	N/A	N/A	N/A
Latin America & Caribbean	339	107 508	0.45	18.2	23.4	9.0	78.0	0.041	0.082
Asia (excluding Japan)	**783**	**893 957**	**0.72**	**32.1**	**25.8**	**33.9**	**57.9**	**0.244**	**0.231**
Mature NIEs (d)	2 121	189 212	1.50	50.1	36.6	51.2	45.8	0.768	0.751
New NIEs (e)	121	18 492	0.20	27.7	15.0	38.7	46.5	0.077	0.055
World (79-84 countries)	**1 304**	**4 684 700**	**0.92**	**36.6**	**24.7**	**34.5**	**53.2**	**0.318**	**0.337**

SOURCE: CALCULATED FROM UNESCO STATISTICAL YEARBOOK 1997. NOTES: (A) ONLY INCLUDING COUNTRIES WITH DATA, AND WITH OVER 1 MILLION INHABITANTS IN 1995. (B) USA, CANADA, WEST EUROPE, JAPAN, AUSTRALIA AND N ZEALAND. (C) INCLUDING MIDDLE EAST OIL STATES, TURKEY, ISRAEL, SOUTH AFRICA, AND FORMERLY SOCIALIST ECONOMIES IN ASIA. (D) HONG KONG, KOREA, SINGAPORE, TAIWAN PROVINCE. (E) INDONESIA, MALAYSIA, THAILAND, PHILIPPINES.

Table 7 shows comparative spending on R&D and scientists and engineers employed in R&D for various regions. SSA performs poorly, particularly for R&D most directly relevant to industrial technology – R&D financed by the productive sector. The available data suggest that by this measure none of the five case study countries spend anything on technological activity. This is not surprising, given the recent history of industrialisation in SSA and its specialisation in natural resource-based and low-technology activities.

Evidence on informal technical effort and technological capabilities in SSA is provided by some recent studies.[4] In general, the findings suggest that external sources of information and learning are poor, with firms forced to rely almost exclusively on internal efforts to build their technological capabilities. This is not by itself a problem, as internal efforts are often the most important source of technological capabilities among successful small-scale exporters in Asia and Latin America (Berry and Escandon, 1994, Levy et al., 1994, Pietrobelli, 1998, Wignaraja, 1998). However, the problem in Africa is that internal technical efforts – however measured – are weak, inadequate and sporadic (Biggs et al., 1995). These efforts are not supported by the S&T system, considered below.

7. SCIENCE AND TECHNOLOGY INSTITUTIONS IN SSA

During the colonial period and even after independence, there was little attempt to develop an explicit science and technology (S&T) strategy in most African countries. S&T policy was pursued implicitly by technical government departments (e.g. medical services, agriculture, mines, geological surveys, industry and education). Sometimes, the organisation of research was handled by inter-territorial research institutions set up by the colonial administrators to cater to the needs of the whole regions. This was the case of West as well as East Africa (Lall and Pietrobelli, 2002). Let us consider some of the main technology institutions.

Metrology, standards, testing and quality (MSTQ)

MSTQ institutions provide the basic infrastructure of technological activity in any country. Standards are a set of technical specifications used as rules or guidelines to describe the characteristics of a product, a service, a process or a material. The use of recognized standards and their certification by internationally accredited bodies is increasingly demanded in world trade. This reduces transactions costs, information asymmetries and uncertainties between the seller and the buyer with respect to quality and technical characteristics. Metrology provides the measurement accuracy and calibration without which standards cannot be applied. The application of standards and the certification of products necessarily imply (accredited) testing and quality control services.

The importance of industrial standards has risen because of the fast pace of technical progress, the growing complexity of new products and the increasing multiple use of technologies. Therefore, standards importantly contribute to the diffusion of technology within and across industries. Most importantly, in a developing country a standards institution can disseminate best practice in an industry by encouraging and helping firms to understand and apply new standards. Redundant experimentation with new technologies is reduced, and enterprises are forced to use a common language that is also shared by the international market. In turn, this reduces the complexity of inter-firm technical linkages and collaboration.

The International Standards Organisation (ISO) has introduced the best known quality management (not technical) standards in use today: the ISO 9000 series. ISO 9000 certification is becoming an absolute must for potential exporters, signalling quality and reliability to foreign buyers, retailers as well as transnational corporations seeking local partners and subcontractors. In the whole of Africa

4 See Biggs et al., 1995, Lall et al., 1994, Lall (ed.), 1999, and Wangwe (ed.), 1995.

(including Northern Africa) only 23 such institutions were operating at the end of 2000 (www.iso9000.org).

In this section we present evidence on standards institutions in the case study countries.[5]

TABLE 8: SUMMARY FINANCIAL INDICATORS OF THE GHANA STANDARDS BOARD

	1994/95	1998/99
Revenues		
Revenues in US$ mill. *	1.46	2.25
Sources of Revenues (%)		
From government scheduled	90	82
From services sold	10	18
Expenditures (%)		
Salaries	60	77
Materials & buildings	4.5	6.6
Training	1	2
Equipment	10	5
R&D	-	-
Others	24.5	9.4
Total	100.0	100.0

SOURCE: INTERVIEWS TO GSB STAFF DURING UNCTAD FIELD MISSION (JAN.2000).
* APPROXIMATE FIGURES DUE TO VARIABLE EXCHANGE RATE.

Ghana: The Ghana Standards Board (GSB) is the main organisation in the country for ensuring industrial quality, through standards, metrology, testing and quality assurance. It was established in 1967 and, despite a good reputation in the region, suffers from several weaknesses. A major shortcoming is its low funding, and especially the share of the budget devoted to activities oriented to the internal development of the Board and its linkages to local industry. Thus, salaries account for an increasing and disproportionate share of the budget (Table 8), while only 2 percent is spent in staff training. Furthermore, no funding is available for any kind of R&D. Total revenues amounted to about US$ 2.2 million, twice as much as in the analogous institution in Uganda (see below), but much less than in other SSA countries. Although the share of self-financing by selling services to local firms is increasing, positively following the targets set by the Ministry of Education, Science and Technology, the Government still contributes 82 percent of total revenues. The lack of funds also accounts for the old and outdated equipment used in some divisions.

Despite the inadequate funding, GSB has some achievements to its credit. The European Union accepts GSB's ability to conduct inspection, testing and issuing of health certificates for exports of fish and fishery products to the EU market. Since 1999, the Japanese Government has recognised the GSB Chemical Laboratory as a accredited institution for chemical analyses and certification of food and food related products exported to Japan, allowing Ghanaian food exporters certified by the GSB to enter the Japanese market without the mandatory local test and chemical analysis. The United Nations Drugs Control Programme has selected GSB to provide training to analysts of controlled drugs for the Anglophone sub-region of Africa.[6]

Of a total staff of 403, the administrative divisions account for 250, large relative to employment in the scientific and technical divisions. Low salaries, fixed to government scales, do not allow GSB to attract the best graduates or to retain good staff.

5 This evidence was collected by the authors in fieldwork funded by UNCTAD, the Commonwealth Secretariat, the European Commission and the World Bank during 2002 and 2001. See Lall and Pietrobelli (2002) for further details.

6 Analysts trained by the GSB over the years have come from Eritrea, Ethiopia, Mauritius, Zanzibar, and other countries.

Zimbabwe: The institution charged with promoting standardisation and quality improvement in Zimbabwe is the Standards Association of Zimbabwe (SAZ), set up in 1957 (originally as an outpost of the British Standards Institute) as a non-government and non-profit making body. It is governed by a General Council which has representatives of the government, local authorities, industry, commerce and professional institutions. It is "subsidised by monies from the Standards Development Levy Fund charged on the wage bill of larger companies; this provided nearly 70 percent of its income in 1996. it also earns income from the Mark Certification Scheme, Registration under Quality Management Standards, Laboratory Testing fees and sales of publications" (SAZ, 1997). The one-fifth proportion of self-financing – although reasonable by African standards – is low by standards of similar bodies in East Asia and developed countries.

In 1999 SAZ had a staff of less than 100, of which about half were scientists and technicians.[7] By 1997, it had prepared a total of approximately 500 standards, mainly for the construction industry: it adopted international standards whenever possible, writing its own standards only when foreign ones were not applicable. Practically all standards are voluntary. SAZ had developed some capability in the ISO 9000 area by 1997, and had internal assessors who certified around 20 companies. However, its promotion of ISO 9000 had not been very forceful. No financial assistance has been offered to firms, even SMEs, to undergo the cost of getting consultancy services, training and equipment for this purpose.[8] Industry was complimentary about the quality of testing services offered by SAZ, but much of this was used by large companies. SAZ appeared to have adequate equipment and well-motivated personnel.

However, SAZ lacks the ability to accredit private testing laboratories, holding back the growth of what is normally a vibrant service industry in most industrializing countries. SAZ is also handicapped by not having a metrology (scientific measurement and calibration of measuring instruments) facility: metrology capabilities are of growing importance to sophisticated industries and an internationally accredited metrology facility is vital to expanding manufactured exports. Most metrology work for Zimbabwean enterprises is done in South Africa and some (for mining equipment) in Zambia. A new metrology facility is to be set up in Zimbabwe under the SIRDC (below). However, the rationale for putting standards and metrology under two different institutions is not clear, since their work is often closely related and most countries have them under one administration.

One of the difficulties facing SAZ in launching a more aggressive campaign has been the shortage of trained staff. Given its low salaries (as in Ghana), SAZ was losing its best staff to the private sector. While this diffusion of skills was not necessarily undesirable from the national perspective, it did mean the weakening a crucial infrastructure body.

Kenya: The Kenya Bureau of Standards (KEBS) was set up in 1974 and by end 1999 had developed around 2,000 standards locally. It is also the repository for a variety (over 150,000) of international and foreign standards, and operates a product certification and several quality certification schemes. It had seven lead assessors in 1998 able to provide ISO 9000 certification, and had certified 10 companies. It also offered quality control laboratories for testing facilities, a metrology division and a calibration division. The calibration standards were traceable to Germany and South Africa. By early 2003 it had

7 Commonwealth Secretariat mission, 1997, Lall, S. Robinson, P. and Wignaraja, G., 1998, and Lall and Pietrobelli, 2002.

8 The UK government, in the heyday of the Thatcher laissez faire approach to manufacturing, promoted the ISO 9000 series by offering subsidies of 50% of consultancy services; the aggressive promotion campaign has led the UK to have the highest number of ISO certificates in the world (Lall, Robinson and Wignaraja, 1998).

a staff of around 650, around 60% of whom were technically qualified. Our impression is that it is the most active and efficient of the five standards bodies studied here.

KEBS is funded by a standards levy on all manufacturers (0.2 per cent of ex-factory sales up to a ceiling of US$ 4,000 per annum), import quality inspection fees, annual government grants and services sold to industry, such as training. However, a relatively small proportion of Kenyan firms demands its services or interacts with it in other ways, perhaps a reflection of the latter's weak capabilities than of the quality of services offered by KEBS. Firms used to complain of long delays in receiving its services around the mid-1990s (Wignaraja and Ikiara, 1999), but the situation appears to have improved somewhat. There has been a significant rise in the number of firms with ISO certificates in Kenya and by 2003, five of the ten KBES standard laboratories and two of its 14 measurement laboratories had been accredited abroad. Its Diamond Mark of Quality is apparently respected locally and regionally.

According to KEBS, the implementation of standards faced problems of skill availability and weak quality culture in industry. KEBS had started its own training scheme and sent people abroad for further training. However, as in Ghanaian and Zimbabwe, trained employees often left KEBS for private industry because of salary differentials.

Tanzania: The Tanzania Bureau of Standards is weaker than its counterparts in Kenya and Zimbabwe. TBS started in 1976, and by 1999 had a staff of 135 (including 80 scientists and engineers) and had written around 700 standards, mostly in the food industry. It complained of extremely low quality consciousness in Tanzania; at that time only two firms (a soft drinks firm and a battery manufacturer, both with foreign equity) had obtained ISO 9000 certification. Its laboratories were not internationally accredited and the Bureau lacked the capability to accredit independent testing laboratories. The TBS earned about 70 per cent of its budget from testing services, a high percentage in comparative terms, but its testing facilities were inadequate for local industrial needs. Many quality tests had to be performed in Kenya and South Africa, raising the cost to local firms.

Uganda: The Uganda National Bureau of Standards (UNBS) became operational in 1989, later than most counterparts in the African region.[9] Strengthening the UNBS had been a key government priority for the period 1994-99: "…. to prepare the necessary standards, to develop policy directives on standardisation, to ensure the application of these standards and to create a quality and standardisation awareness in all sectors of the economy, will be a key priority in implementing industrialisation and export promotion policies" (Ministry of Trade and Industry, MOTI, 1994).

However, this target had not been met by the late 1990s. There was little awareness of quality among Ugandan entrepreneurs (no Ugandan firm had been awarded ISO 9000 certification), and relatively few Ugandan firms demanded UNBS services. Ninety percent of the UNBS resources come from the government, which has committed about US$1 million per year to the institution but had disbursed less than 70 percent of this sum. The budget of UNBS was thus considerably smaller than of the institutions analysed above. The staff numbers were also smaller: 80 overall, with 30 technicians and 20 scientists with university degrees. UNBS laboratories were not internationally accredited. The Bureau did not have the capability to accredit independent laboratories.

9 In conjunction with the Kenyan and Tanzanian standards bureaux UNBS is also involved in the elaboration of East African harmonised standards within the framework of East African Co-operation.

R&D institutions

The largest and most active public R&D institutions in most African countries are involved in agriculture rather than manufacturing. As private sector R&D in industry is virtually absent (apart from South Africa, see UNIDO, 2002), public institutions have a vital role to play in local efforts to absorb, adapt and improve imported technologies.

In Uganda, the largest R&D body is the National Agricultural Research Organisation (NARO), which, since its establishment in 1991, has had an annual budget of around US$10 million (the government contributing 30 percent). NARO employs 210 scientists and over 600 support staff, has abundant financing from international donors and the private farming sector, and has strong links with Makerere University and other institutions in Kenya and in East Africa.

Ghana's Food Research Institute (FRI) was established in 1963, and has a staff of 172, of which 36 are technically qualified engineers, food scientists and biochemists, microbiologists, nutritionists and mycotoxicologists (five hold PhDs). Its staff complement is larger and better qualified than that of its sister Industrial Research Institute (IRI, see below). Over the years, FRI has been substantially funded by international aid, with sponsors ranging from the World Bank (through the NARP), to IFAD, UNDP, DANIDA, DFID, the Dutch Government and USAID. This reflects the priority attached by foreign donors to the agricultural sector, and mainly to the staple food production and storage. The official reports of FRI state that it has been actively transferring its technologies and R&D results to the agricultural sector (CSIR, 1999).[10]

For many years one of the main weaknesses of FRI has been the lack of a unit formally responsible for providing services to the public. This was partly addressed by the creation of a Business Development Division, but the ability of this Division to disseminate scientific information with commercial potential and to win contract research projects is still limited. It would appear that the problem lies with the corporate values of the institution: scientists and technical personnel see little value in developing linkages between basic research, applied research and productive activities.

While agricultural research organisations have benefited from donors' emphasis on food security and basic needs, manufacturing R&D has suffered from neglect in Uganda (as in other African countries). The Uganda Industrial Research Institute (UIRI) has been under-funded and poorly staffed despite its wide-ranging mandate "to undertake applied industrial research and to develop and acquire appropriate technology in order to create a strong, effective and competitive industrial sector for the rapid industrialisation of Uganda" (official leaflets).

UIRI was conceived of in the 1970s by the East African Community (EAC) as a regional project to promote research in industry. During the days of the EAC, industrial research used to be conducted by the East African Industrial Research Organisation based in Nairobi. In 1974/75 the Research Council of the EAC decided to decentralise industrial research in the three partner states (Uganda, Kenya and Tanzania) on the basis of local raw materials and resources. Kenya set up the Kenya Industrial Research and Development Institute (KIRDI) and Tanzania the Tanzania Industrial Research and Development Organisation (TIRDO) (on both, see below); Uganda delayed. After the break-up of the EAC in 1977, each state had to take over the financing of its R&D institutions. Prolonged economic difficulties in Uganda meant that the industrial research institute was not set up till 1994, when the government

10 These include: the improved fish smoking equipment, locally known as the Chorkor smoker; instant foods such as fufu flours from plantain, cocoyam, yam and cow-pea, fermented cassava meal, improved kokonte powder.

received an interest-free loan of US$6 million from China. China also gave an additional US$3.6 million for laboratory and office equipment, workshops, generators and technical assistance.

By end 1999 UIRI employed 35 people, with 2 with Masters' and 16 with undergraduate degrees. The institution faced difficulties in recruiting good scientists at the low salaries offered. The government funded recurrent activities (US$250,000 in 1998/99), with most of the Institute's budget used to pay salaries (35 percent), and materials, utilities, buildings and equipment (over 50 percent). Only 10 per cent of the institution's resources went into R&D, which consisted essentially of relatively low-level adaptive work. Much of its services are for relatively simple testing, trouble-shooting and repair and maintenance of equipment rather than to research or development.[11] The number of clients has grown from 50 in 1998 to almost 100 in 1999, still a small number even for Uganda's tiny industrial sector.

UIRI staff could not provide a single instance of UIRI technologies being used in commercial production by private enterprises. The Institute's activities appear to be supply-driven and their research output is of little use to most industries. Nor is there any capability to market research results. The inability to identify the problems of clients, especially smaller ones, was acknowledged by the staff. UIRI does not provide assistance to enterprises in finding and importing foreign technologies. In sum, UIRI is a largely dormant institution with an ambitious mandate unrelated to its own conception of its role and functions.

In Tanzania, the Tanzania Industrial Research and Development Organisation (TIRDO) was set up in 1979, following the collapse of the EAC, to conduct industrial R&D and offer consultancy services to industry. By end 1999, it had around 75 staff, of which 35 were scientists and engineers. TIRDO offers a variety of services and has an instrumentation centre, a chemical laboratory, an energy management centre, a materials laboratory, a mechanical workshop, a furniture workshop, a trouble-shooting and advisory service centre on technology selection and process control and optimisation, a National Cleaner Production Centre (part of a UNIDO/UNEP project) and an industrial information centre. The objectives with which TIRDO was set up were fairly modest – using local raw materials, developing simple appropriate technologies and providing support and information services to local industry and SMEs. They were well suited to a country at Tanzania's level of industrial development.

Even these modest objectives have not been well served. There is little interaction between TIRDO and the private sector; what exists is largely limited to large firms seeking specific technical services like testing. Hardly any of the technologies developed by TIRDO have been used by industry and liberalization has not stimulated any new demand for its services. SMEs rarely use TIRDO technical services. Its image with industry is poor, and its capabilities lack credibility. Most of the laboratory equipment, first given by donors, is now obsolete. TIRDO is rarely commissioned technology projects by industry[12] and has never taken out any patents. It has developed process know-how for such products as caustic soda, chalk and chipboard manufacturing, largely copying mature technologies from other developing countries.

11 The main operational projects include: the Value Added Meat Products to improve meat processing capabilities of Ugandan firms, funded by FAO and GTZ from 1997 to 1999 (US$1.4 million); the Fermented African Dairy Products Project, essentially a training project funded by DANIDA and the World Association of Industrial and Technological Research Organisations (WAITRO) from 1997 to 1999 (about US$ 160 000).

12 The only exception mentioned was the development of particleboard based on rice husk. This was undertaken by an MSc student at the University of Dar es Salaam using TIRDO facilities, and did not involve the institute's research staff.

In 1998/99, 58 per cent of the TIRDO budget came from services sold to industry, with the remainder coming from the government budget. Due to financial pressures, there is almost no money for R&D activity. TIRDO salaries are tied to government scales, reducing its attractiveness to young graduates or to ambitious qualified people generally. While employees are allowed to keep 30 per cent of the value of services sold to industry, this does not provide sufficient incentive to stimulate any genuine technological activity.

A detailed study of TIRDO (Bongenaar and Szirmai, 2000) examined 12 of the 25 technology projects undertaken during 1979-96 (the small number of projects over the 27 years is itself noteworthy). The authors found that most projects were undertaken at the initiative of TIRDI staff rather than at the request of industry. Project evaluation did not look in depth at its technical or economic desirability for the economy or at its environmental aspects. The original technology on which projects were based was imported and mostly over five years old. Success was defined by the technical objectives of the staff rather than by application in industry or commercial success. There was no attempt to relate technological efforts to industrial competitiveness. Once developed, marketing of the technologies to potential users was weak. According to these authors, not one project reached the stage of technology transfer from TIRDO to private industry.

This suggests that TIRDO is also a largely dormant institution. Despite its potential role in supporting, stimulating and producing industrial technology, it has not so far been able to link itself to industry, identify industrial needs or provide new technologies. It survives by providing low-level services that would normally be provided by private firms. Its staff is poorly paid and demoralised. There is little managerial initiative to improve its functioning.

The Kenya Industrial Research and Development Institute (KIRDI) is the main industrial R&D institution in this country, and one of eight R&D institutes established in 1979 after the break up of the EAC. Its mission was "to enhance the national industrial innovation process through the development of a sufficient national capacity in disembodied and embodied industrial technologies for the attainment of a self-sustaining industrialisation process." In 1997, a study by Bwisa and Gacuchi (1997) emphasised the lack of links between research institutes/universities and industry in Kenya. However, a recent reorganisation and reorientation of KIRDI under a new director sought to make it more relevant to industry.

In 1994, the findings of a UK team examining R&D institutions in Kenya led the government to reorient them to industrial needs.[13] KIRDI was placed under a new director, who redefined its work to move from R&D to industrial technology support and reorganised the institution.[14] Its focus remained relatively simple food-processing technologies, where it claims success with diffusing its technologies and equipment. However, it still has low interaction with the formal manufacturing sector and earns little from selling technological services to industry (apart from some testing services and the sale of die making equipment). It provides some training to small and micro enterprises and has participated in a World Bank financed project on technical services to micro enterprises. It has a staff of around 50 professionals (out of a total staff of around 250), but needs to offer higher salaries and buy more advanced equipment to make its effort relevant to the formal manufacturing sector. Following this

13 See Lall and Pietrobelli (2002) for details.

14 The reorganisation involved substantive retrenchment, from 700 to 289, with almost all the shedding confined to support staff rather than technical personnel. Productivity indicators were put in place, based on impact on industry rather than research publications.

reform, all the six centres in KIRDI offer consultancy services, and are allowed to retain all their earnings except for costs and a 15 per cent overhead.

In Zimbabwe, despite its large manufacturing sector and reasonable base of industrial capabilities (Lall, 1999)[15], there were no public R&D institutions in manufacturing technology till the end 1990s. The only bodies that could do R&D for industry were the engineering departments at the university, but these, like most traditional universities, had few links with enterprises. This may not have greatly disadvantaged Zimbabwe till now, as the relatively sheltered environment did not require firms to use advanced techniques that required specialised technology institutes or contract R&D. However, liberalization has put increasing pressure on firms to improve their technology and use existing technologies more efficiently.

In response, the government launched an ambitious programme in 1997 of building seven R&D institutes under the Scientific and Industrial Research and Development Centre (SIRDC), placing the Centre directly in the President's office.[16] At the time of visiting this Centre (1998) there was little to report as the research laboratories were still under construction. The subsequent political turmoil has inevitably negatively affected the programme.

Ghana's Industrial Research Institute (IRI) was founded in 1967 with a mandate to undertake research into process and product design, to adapt imported technology, provide scientific instrumentation and calibration and repair precision equipment. Its activities today are essentially related to repair, maintenance and calibration of equipment and machinery, and the emphasis has

15 The comparison of technological capabilities in Zimbabwe with those in Kenya and Tanzania suggested that its industrial enterprises were technologically in advance of its neighbours (Lall, 1999). This was also the conclusion of the total factor productivity analysis in a World Bank study (Biggs et al, 1995), showing that average technical efficiency was higher in Zimbabwe than in Kenya or Ghana. However, Lall (1999) argued that capabilities in Zimbabwe were well below levels reached in other developing countries, and that this was being manifested in the competitive difficulties facing enterprises being exposed to direct import competition.

16 The seven research institutes planned in Zimbabwe are:

Biotechnology Research Institute: This institute, with five divisions, will work on such projects as the development of drought resistant maize species, micro propagation of disease resistant potatoes, and food irradiation.

Building Research Institute: The institute will use local materials and waste materials for lower cost construction, get lower cost technologies from other countries and develop cheap concrete panels for walls and roofing.

Environment and Remote Sensing Institute: This institute was one of the first to become operational, and by 1998 had a remote sensing and information system and an environment management unit.

Production Engineering Institute: This institute is to provide a range of common services and technological assistance to manufacturing industry. It will have a foundry, machine shop, fabrication workshop, CNC machine section, workshop with tribology, corrosion and other testing facilities, and materials science. It will provide pilot plant facilities and provide consultancy services to industry. This institute is not intended to do research and development; thus, it will be more of a productivity centre than a normal technology institute. This is likely to be extremely useful if it lives up to expectations: it will help industry to improve quality and develop new products and processes, diffuse technology and provide trouble-shooting services. The intention is to work a great deal with SMEs and informal sector enterprises, providing training for free and also management, finance, business and other forms of assistance that such enterprises need. It plans to have a team to work with managers, giving advice on entire production systems and devising systems for improving them. The fact that the institute is designed to provide productivity services also means that Zimbabwe would still lack a full-fledged R&D centre for industry.

Electronics Technology Institute: This institute is intended to provide systems engineering services rather than electronics manufacturing or design technology. It will allow Zimbabwe to 'open up' and adapt software packages that are presently imported in their entirety. It may give it a head start in software production and may be a source of comparative advantage in the region, though it is difficult to see Zimbabwe emerging as a competitor in the larger arena.

Energy Technology Institute: This will work on energy conservation, non-conventional sources of energy and efficient generation from conventional sources.

National Metrology Institute: This was mentioned in the section on standards, and in 1998 was still at the planning stage.

been increasingly towards servicing enterprises. Following the recent drive towards commercialisation, IRI research programmes have become oriented to 'development' rather than research. While this is clearly a move in the right direction, the results so far have been disappointing. As with the institutions in Kenya and Tanzania, IRI has not developed the capabilities to conduct useful R&D for industry and to establish close links with its prospective clients.

In 2000 the IRI had a staff of 135, of which 38 were researchers (two with PhDs and five with MScs). Salaries, fixed to government scales, were lower than alternatives like jobs funded by foreign aid. In 1996, a merger with another public institution further reduced the low levels of official funding of IRI (Lall et al., 1994:43). In 1999 the IRI received about US$370,000 from the government, of which only 5 percent was devoted to research. These values amounted to tiny fractions of the public budget, signifying the low priority attached to industrial support work.

Official reports claim IRI developed several technologies, processes and products, and transferred some to industry. Examples given are cassava processing, production of liquid soap from the ash of agricultural waste and soy oil refining (CSIR, 1999). While it is difficult to evaluate the economic impact of such transfer, it does appear that IRI lacks a systematic strategy of assessing technology needs in industry and to reach its target customers. There is little close interaction with manufacturing firms. As in Tanzania, the Institute's activities appear to be largely supply-driven, their orientation determined by the (limited) capabilities available in-house.

By admission of senior staff, IRI is under-funded, lacks the infrastructure and equipment needed for effective R&D and has insufficiently trained staff. Though its clients have grown in number from 30 in 1997 to 100 in 1998 and 114 in 1999, this is a tiny number considering that IRI is the only public research institute for the industrial sector in Ghana. As with its counterparts in Tanzania and Uganda, IRI seemed to lack the capabilities, motivation and incentive structure to assess and meet the growing technological needs of local manufacturing industry. It is, however, worth noting the existence of a more successful institute in the country: the Ghana Regional Appropriate Technology Service (GRATIS). However, as GRATIS is concerned with the development and diffusion of intermediate technology and rarely deals with modern industry, it is not considered in this paper.

Summarising on R&D institutions in the five countries, the most active (and well-funded) ones have so far focused on agriculture and not manufacturing. Industrial R&D institutes have tended to perform poorly, failing to offset (and to some extent reflecting) the paucity of technological activity in industrial enterprises. Interestingly, at least at the time of this study, there was little correlation between the quality and effectiveness of industrial R&D institutions and the level of industrial development. Zimbabwe may, however, prove to be an exception if its ambitious plans for the seven new R&D institutions are successful.

There were several common threads running through the industrial R&D institutions in the region. They generally lacked the facilities (physical and human) to provide meaningful support to industrial enterprises. Their personnel tended to be poorly paid and motivated, with little incentive to reach out to and interact with their prospective clients. They had no means of assessing the technological needs of industrial enterprises or of diffusing to them the technologies they had created (or, more commonly, adapted). As a result, the institutions carried little credibility with the private sector and had very few continuous linkages with it apart from providing routine testing services. And they were not (unlike similar institutions in more advanced countries that also failed to link up to industry) conducting advanced research for publication in international journals – they lacked the capabilities and resources to do so.

Their poor performance reflected not just internal constraints, but also technological apathy in much of local industry. Most enterprises were not technologically active and aware; few had responded to liberalization by mounting technology-based upgrading strategies. In the absence of technological activity in enterprises, however, it is difficult for R&D institutions to provide effective assistance (Rush et al. 1996). Governments had not given much priority to promoting industrial research in these countries, in private or public institutions. This reinforced the general feeling of marginalization and discouragement in most institutions.

To sum up on institutions, the picture of national technology systems emerging from this sample is discouraging; what is worse is that it is (South Africa excepted) likely to be representative of the whole SSA region. The main elements of the system are weak. The technology infrastructure is small, passive and largely ineffective. It is often poorly funded and motivated and tends to be de-linked from industry. Its ability to develop, adapt and disseminate industrial technologies is weak. It has little awareness of the needs of local industry, even less of how new technologies can be introduced to potential users. Enterprises, for their part, conduct little formal technology activity and generally lack awareness of the need to do so to cope with the severe challenges posed by import liberalization. The government is largely indifferent to industrial technology and provides little support to inherited technology institutions. Nor does it do much to promote a more active technology culture in industry.

Not only is each element weak, there is little systemic interaction between them to support industrial technology development.[17] An additional dimension of the problem, not discussed in this paper, is the similar absence of linkages between industry and educational institutions. Very few firms collaborate with universities or polytechnics, despite the reservoir of theoretical and engineering knowledge there.

All countries that have industrialized successfully, as in Asia or Latin America, have developed strong public technology infrastructure institutions sector to support technological development in industry. More recently, they have undertaken reforms and new measures to strengthen their linkages with industry (Amsden, 2000, Lall, 1996). Private enterprises in some newly-industrializing economies are Thanks, John. I really appreciate it. acquiring a technology culture – they undertake meaningful R&D in-house and contract R&D to other institutions. If African countries are not able to mount a similar reform, it is difficult to see how their industrial enterprises will become dynamic competitors in world markets.

8. CONCLUSIONS

Sub-Saharan Africa's recent industrial and technological performance is disappointing. The manufacturing sector is tiny in most countries and has been losing shares in world markets despite some years of liberalization and opening up to globalised production. Enterprises are smaller, less efficient and less innovative than counterparts in other developing countries. Quite apart from the political and governance problems affecting the region, there are binding structural constraints on industry (UNIDO, 2003, Lall and Wangwe, 1998, Collier and Gunning, 1999). The supply of modern skills is inadequate and the physical infrastructure is weak and often deteriorating. In addition, this paper has noted the inadequacies of the technology system that underlies industrial competence

17 See Lall and Pietrobelli (2002), Biggs et al. (1995), Enos (1995), Lall and Wignaraja (1998), Latsch and Robinson (1999), Wignaraja and Ikiara (1999) and Wangwe and Diyamett (1998).

and dynamism. This aspect has been unduly neglected in the ample literature on African economic problems, but is of vital significance to long-term development.

This paper suggests that despite liberalization and structural adjustment in much of the region, the manufacturing sector is lagging in international competitiveness – a far less optimistic picture than portrayed by the World Bank in the early nineties (World Bank, 1994). Unlike many other industrializing countries in East Asia, there has been little attention given to the technology system. Even in the most advanced industrial economy in the region after South Africa – Zimbabwe – suffers from a weak and slothful technology system. In general, the MSTQ infrastructure is weak, R&D support is minimal and linkages between public institutions and universities, on the one hand, and industrial enterprises, on the other, are negligible.

The strengthening of the national technology system is necessarily a long-term process. It entails the gradual building of institutions, changing of attitudes, creation of new links and networks and, inevitably, substantial resources over a lengthy period. Needless to say, it also needs a conducive social, political and economic setting in which enterprises, governments and institutions can plan and implement long-term strategies. It is beyond the scope of this paper to discuss the array of policies needed to do all this in Africa (but see Lall and Pietrobelli, 2002, for specific recommendations on technology development drawing upon the experience of other industrialising countries). However, we conclude by noting two priorities for policy: technology strategy formulation and co-ordinating and planning the technology system.

Technology strategy formulation is particularly weak in Sub-Saharan Africa. In Kenya, for instance, there is no institutional mechanism for evaluating and setting S&T priorities. In Ghana the strategy still consists largely of statements of good intent and over-ambitious plans. Overall S&T policy exists largely on paper, and comes very low in the pecking order of government priorities. This differs greatly from the dynamic Asian developing countries (Amsden, 2000, Lall, 1996), where technology upgrading and strategy have become important policy priorities. The most fundamental policy gap in Africa is perhaps the lack of official appreciation of the importance of technology development to manufacturing growth and competitiveness – without such appreciation clearly no effective strategies can be formulated or implemented. Governments in the region pay little attention to technological needs in industry or to the promotion of technological activity within firms or in support institutions. Not only does industry lack a technology culture, so does the government. No national technology system can function effectively unless such a culture is created.

Coordinating and planning the technology system is another area of policy concern, in turn reflecting the low priority attached to technology. In most of Africa, technology policy formulation is uncoordinated and spread over a number of different ministries and departments. Where institutions exist to formulate S&T policy (COSTECH in Tanzania, CSIR in Uganda or MEST in Ghana), they tend to be too weak to affect other ministries and to coordinate their efforts. Government agencies generally guard their turf jealously, unwilling to part with the information, functions and resources that a coordinated effort would need.

Fragmentation means that partial objectives are pursued without reference to national goals. What is more, the private sector is rarely involved in the design and implementation of a technology strategy. Private sector business associations do not, for their part, formulate technology strategies for their sectors or members, and do not attempt to influence government policy in this respect; most tend to stick to their traditional role of seeking government favours and extending protection. However, no technology development strategy can succeed unless the private sector is convinced of its need and is willing to play its part. The most effective technology strategies in East Asia, for instance, have involved private sector collaboration and resources. R&D linkages have generally been stimulated by schemes where private firms financed half the cost.

Ultimately, and not surprisingly, the development of strong technology systems in Africa needs a systemic change in all elements. The institutions themselves cannot accomplish much unless the government and the private sector also commit themselves to technology development. At this time, the possibility of such a change appears rather remote. To the extent that technology upgrading is a necessary element of industrial development in a liberal and globalised economy, this is a matter of grave concern.

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