National Technology Systems in Sub-Saharan Africa

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Abstract: There is an increasing concern among policy-makers in many countries about national 'competitiveness' and the technological dynamism required to be competitive. 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. This paper contributes to this debate by specifically focusing on Sub-Saharan Africa (SSA) and using original microeconomic evidence on scientific and technological infrastructure.

In this region, in spite of continuing liberalization and openness, competitiveness is worsening, and deficiencies in the science and technological infrastructure seriously constrain industrial performance.

Keywords: technology; innovation; national innovation systems; technology transfer; Sub-Saharan Africa.

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Biographical notes: Sanjaya Lall passed away on 18 June 2005. He was Professor of Development Economics at the University of Oxford, International Development Centre, Queen Elizabeth House. He was a pioneering economist and a world leading scholar. His areas of specialisation included industrial economics and innovation and technology in developing countries. He has published extensively on these issues.

A prolific researcher, he published 33 books and hundreds of internationally acclaimed articles. His most recent books include the following: Und*erstanding FDI-Assisted Economic Development* (with R. Narula), Routledge, 2005, *Competitiveness, FDI and Technological Activity in East Asia* (with S. Urata), Edward Elgar, 2003, *Failing to Compete: Technology Development and Technology Systems in Africa* (with C. Pietrobelli), Edward Elgar, 2002, *The Economics of Technology Transfer*, Edward Elgar, 2001, *Competitiveness, Technology and Skills*, Edward Elgar, 2001.

He was also Principal Consultant for the UNIDO *World Industrial Development Report* and for the UNCTAD *World Investment Report* for several years. He also acted as Consultant for the World Bank, the European Commission, the Inter-American Development Bank, the Asian Development Bank, UNDP and many other UN agencies.

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He has also acted as Consultant to the European Commission, the Inter-American Development Bank, the World Bank and most United Nations agencies.

Sanjaya Lall passed away on 18 June 2005 in Oxford at his home from a heart attack before this article could be published. I was his student and eventually became his colleague and friend over the years.

Sanjaya was a pioneering economist who was globally renowned in the field of multinationals, technology and development. For such a world leading scholar, he became a truly selfless friend to me.

I shall always remember his intellectual leadership, originality and depth, as well as his freedom of thinking. His interests were in the details of firms' learning and innovation, of transnational corporations and foreign investments, of technology and his-state-of-the-art ideas on technological 'capabilities'.

His intellectual generosity, his enthusiasm and passion for development that he conveyed and shared were invaluable to his students, friends and colleagues.

He truly had admirable qualities. Among them are his loyal and warm friendship, his love for life and his capacity to see and enjoy the good and beautiful sides of life, his inextinguishable curiosity and genuine enthusiasm, his devotion to the cause of understanding the sources of development and contributing to make it happen, and his intellectual rigour and honesty. Our lives would have been more lonely without him. May the Lord watch over his family and loved ones.

1 Introduction

National Innovation Systems (NIS) now play a major role in the literature on technology policy in industrialised countries. The idea that innovation occurs in a 'system' – a set of interacting enterprises, institutions, research bodies and policymakers 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 importance of continuous interaction between agents (Nelson, 1993). However, the concept of an innovation system is not new. In the first half of the 19th century, for instance, Friedrich List wrote about a 'National System of Political Economy' in analysing the strategy that Germany needed to overtake the more highly industrialised England (List, 1841). His concept contained the seeds of what we call a 'System of Innovation' today.

In contrast, research on developing country innovation systems is relatively recent, and has continued to lag despite some notable initial efforts.[2] This is surprising, since the need for conscious and purposive technological effort in developing countries, even if they rely primarily on imports of technology, is widely accepted. It is likely that there are similar systemic elements (to NIS in developed countries) that affect their ability to access, master, adapt to and improve upon imported technologies (Freeman, 1995,p.20). And it is likely that these elements differ across countries – this is vital to explaining the widening gap between a small group of successful industrialising countries and the rest of the less-developed world, what Abramovitz (1986) terms the 'forging ahead', 'catching up', 'falling behind' of economies.

The analysis of NIS in industrial economies has increasingly focused on R&D and frontier innovation rather than less formal kinds of technological effort. This may be justifiable, since routine forms of technological effort and capabilities are more widely dispersed and approach a basic minimum level in mature economies. It is valid therefore to attribute differences in technological performance more to R&D effort by enterprises and technology support provided by the system of institutions and property rights within which they function. Proprietary innovation technology creation is indeed the most important aspect of innovation in industrialised countries (Metcalfe, 1995,p.39).

In most developing countries, the nature of technological effort is quite different. This does not mean that the effort is not as important to their development, or that the system within which it takes place is less significant. As noted, the effort is vital – it is only countries that build strong technology systems and develop the necessary capabilities that succeed in developing strong and competitive industrial sectors – and the system is critical to sustaining the effort. However, since the nature of technological needs and of the market failures that surround technological effort differs between developed and developing countries, the innovation system also differs in some respects. Developing countries have a greater need to build the initial base of capabilities and so need to support the infant industry-learning process. Their markets and support institutions are less developed, and so less responsive to enterprise needs. Information networks and clusters are thinner. In many cases, the macroeconomic framework for industrial and technological activity is less conducive (more prone to instability). The entrepreneurial capacity to undertake risky technological effort may also be less developed, and the financial system less geared to supporting such effort.

This is why the analysis of the innovation system in developing countries has to be different from that of mature industrialised countries. Since the bulk of technological activity in the former concerns the absorption and improvement of existing technologies rather than innovation at the frontier, we prefer to use the term 'national technology system' in developing countries rather than 'national innovation system'.

We must stress 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).[3] This needs an efficient 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 they 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, the former with an established industrial sector and the latter with a very small one. Kenya and Zimbabwe have the largest history of industrialisation in the region after South Africa, while Tanzania has one of the weakest industries. Section 2 provides some background on the region.

2 Background

The poor industrial performance of SSA is well known.[4] Much of the industrial sector has been state-owned, oriented to the local market and technologically backward. Despite liberalisation 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) (Gibbon, 2003). 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 structural shift. 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. The bulk of its exports still come from such unprocessed products: in 2000, for instance, they accounted for 59% of the African exports including South Africa, and for 75% excluding South Africa. The comparable figure (in 2000) was 15% for the world as a whole, 7% for East Asia and 28% for Latin America.

As we are concerned with manufacturing, let us consider the performance of manufactured exports and value added for the sample countries and the region, benchmarked against some international comparators (Tables 1 and 2). Manufactured exports are classified according to technology categories developed by Lall (2000).

Table 1 Manufactured exports by SSA and selected developing countries ($ million)

	1980–1981					*2001–2002*				
	Total	*RB*	*LT*	*MT*	*HT*	*Total*	*RB*	*LT*	*MT*	*HT*
Kenya	706.7	606.0	58.0	31.0	11.8	829.0	610.2	98.1	78.5	42.2
Tanzania	56.7	38.4	14.5	1.9	1.9	206.9	163.6	34.4	7.2	1.7
Uganda	12.0	9.9	0.1	1.8	0.2	63.0	35.3	7.6	15.0	5.1
Ghana	144.3	135.4	3.0	2.6	3.2	486.9	382.9	73.1	25.1	5.9
Zimbabwe	360.5	97.2	84.4	173.6	5.3	1093.3	472.5	272.4	321.6	26.8
South Africa	6490.4	4059.6	1096.0	1224.3	110.5	17,920.3	7096.5	2425.0	7633.0	765.9
India	4901.9	1431.3	2489.9	779.5	201.1	43,927.6	15,881.4	18,095.7	7055.4	2895.0
China	N/A	N/A	N/A	N/A	N/A	302,081.7	24,146.0	126,256.5	74,216.0	77,463.2
Korea	16,314.5	2156.7	8124.0	4286.8	1746.9	157,136.5	15,881.4	24,705.0	65,004.8	51,545.4
Malaysia	6121.3	3943.5	432.0	462.8	1283.0	86,624.3	15,500.3	7874.9	18,084.8	45,164.3
Thailand	2258.4	944.5	709.7	564.6	39.7	52,386.7	7939.2	12,173.2	15,282.1	16,992.2
Kenya	100	85.8	8.2	4.4	1.7	100	73.6	11.8	9.5	5.1
Tanzania	100	67.7	25.7	3.3	3.3	100	79.1	16.6	3.5	0.8
Uganda	100	82.7	1.1	14.7	1.6	100	56.0	12.0	23.9	8.1
Ghana	100	93.9	2.0	1.8	2.2	100	78.6	15.0	5.2	1.2
Zimbabwe	100	27.0	23.4	48.1	1.5	100	43.2	24.9	29.4	2.5
South Africa	100	62.5	16.9	18.9	1.7	100	39.6	13.5	42.6	4.3
India	100	29.2	50.8	15.9	4.1	100	36.2	41.2	16.1	6.6
China	N/A	N/A	N/A	N/A	N/A	100	8.0	41.8	24.6	25.6
Korea	100	13.2	49.8	26.3	10.7	100	10.1	15.7	41.4	32.8
Malaysia	100	64.4	7.1	7.6	21.0	100	17.9	9.1	20.9	52.1
Thailand	100	41.8	31.4	25.0	1.8	100	15.2	23.2	29.2	32.4
Memo item: distribution by regions (%)										
World	100	25.4	18.8	41.9	13.9	100	18.5	17.6	40.2	23.8
Industrialised	100	22.6	17.8	44.6	15.0	100	19.6	15.3	42.3	22.8
All developing	100	40.9	32.5	17.0	9.5	100	14.7	20.8	37.0	27.5
SSA*	100	89.3	6.3	3.0	1.4	100	58.2	25.4	14.8	1.6
East Asia	100	30.5	37.7	19.1	12.8	100	11.2	20.8	36.7	31.3
Latin America	100	71.9	15.6	10.2	2.2	100	21.6	17.2	43.6	17.6

Notes: RB is 'resource based'; LT is 'low technology'; MT is 'medium technology'; HT is 'high technology'. The items included under these headings are given in Lall (2000).

SSA* stands for Sub-Saharan Africa excluding South Africa.

The starting year for Zimbabwe is 1985.

Source: Calculated from United Nations COMTRADE Database

Table 2 Manufacturing value added in selected SSA countries and comparators

	Share of MVA in GDP (%)		*MVA value ($USm. current)*		*Growth (%)*	*MVA per capita ($US)*		*Growth (%)*	*Equipment % MVA*	
	1980	*2002*	*1980*	*2002*	*1980–2002*	*1980*	*2002*	*1980–1996*	*1980*	*2000*
Kenya	10	13	796	1603	3.2	46.8	51.7	0.5	15	9
Tanzania	11	8	555	751	1.4	29.2	21.5	–1.4	8	5
Uganda	4	10	53	580	11.5	4.1	23.2	8.2	…	…
Ghana	11	9	347	554	2.1	31.5	27.7	–0.6	2	…
Zimbabwe	23	13	1248	1080	–0.7	178.3	83.1	–3.4	8	22
South Africa	22	19	16,607	19,806	0.8	572.7	440.1	–1.2	21	20
India	14	16	27,422	81,628	5.1	39.9	77.8	3.1	25	20
China	33	35	81,836	443,118	8.0	83.4	346.2	6.7	22	30
Korea	23	29	18,260	138,240	9.6	480.5	2880.0	8.5	17	45
Malaysia	19	31	5054	29,419	8.3	361.0	1225.8	5.7	20	46
Thailand	23	34	6960	43,148	8.6	148.1	695.9	7.3	9	…

Source: World Bank (2004)

Table 1 shows the weak performance and underdeveloped technological structure (*i.e.*, with low shares of medium- and high-technology products) of manufactured exports by the sample economies. Zimbabwe is, as noted, an outlier, with a relatively advanced medium-technology manufacturing sector (making machinery and intermediates like steel and chemicals). Its recent political difficulties, however, have led to a fall in industrial production in recent years.

3 National technology systems and developing countries

This section deals briefly with the 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 this 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 track, 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. Moreover, in most developing countries industrial enterprises conduct only a small fraction of total R&D; public institutions are responsible for the bulk, often in isolation from the productive sector.

The way in which knowledge is used differs with the 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 depend 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 the effectiveness with which countries have undertaken learning (Lall, 1996; Pietrobelli, 1999). 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.

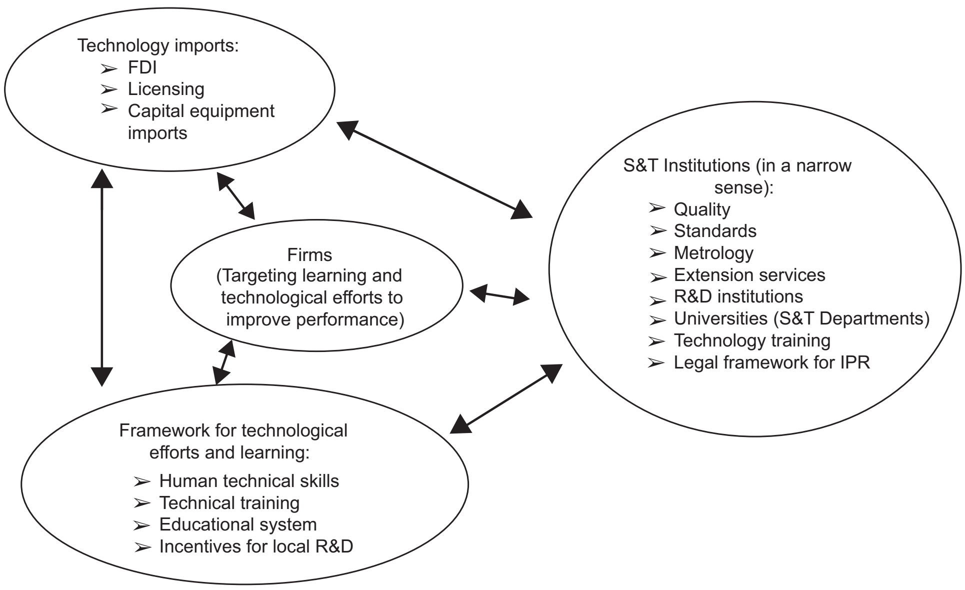
The rise of globalised production under the aegis of TNCs reduces to some extent the need for building domestic capabilities. TNCs provide affiliates with intangible assets (skills, technology, production expertise, training and so on), so that the host economy needs to offer correspondingly less 'ready-made' 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 are needed, there is again a need for local capabilities.

The evolutionary school argues that the pattern of innovation depends on much more than the behaviour of individual firms (Metcalfe, 1995,p.42). 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. While firms are the primary actors in the generation of technological artefacts, their activities are supported by the accumulation of knowledge and skills in a complex *milieu* of other research and training institutions. Technology policy must necessarily encompass this wider context. 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. The component institutions of the system are first of all private firms working individually or in collaboration, but also universities and other educational bodies, professional societies and government laboratories and research institutions, private consultancies and industrial research associations.

In the present paper, we cannot analyse enterprise behaviour and rely on other studies for this.[5] Our focus 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, and 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. In most of SSA, the public sector plays a central role.

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. Figure 1 portrays the main components of and interactions in a National Technology System.

Figure 1 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 imports like copying, migration, trade fairs, journals and the like, but these are difficult to measure and so are not considered here.

4.1 Capital goods imports

Table 3 shows the values of such imports (total and per capita), the share of total imports and the growth rate for 1990–2002. Africa as a whole and most sample countries have very low per capita values of equipment imports (Zimbabwe is again the exception). The only other comparator country in the table that imports less is India, which has built up a large and highly protected capital goods sector. East Asia largely relies heavily on capital equipment imports; while a significant part of such imports consists of electronic components for (export-oriented) assembly, it is also true that high rates of industrial growth there have been accompanied by rapid and continuous upgrading of the capital stock, with new 'embodied' technology.

Table 3 Equipment imports by sample countries and comparators

	Equipment imports ($USm.)		*Per capita ($)*		*As % of total imports*		*Growth of equipment imports (%)*
	1990	*2002*	*1990*	*2002*	*1990*	*2002*	
Kenya	482.1	481.1	19.9	15.5	22.6	15.6	–0.02
Tanzania	..	385.8	..	11.0	..	22.8	..
Uganda	..	174.5	..	7.0	..	16.2	..
Ghana	..	447.6	..	22.4	..	16.5	..
Zimbabwe	452.9	522.4	46.2	42.5	24.5	21.2	1.20
South Africa	..	7425.8	..	165.0	..	28.3	..
India	3262.9	9612.5	3.8	9.2	13.7	15.7	9.42
China	15,550.0	125,421.5	13.7	98.0	29.1	42.5	19.00
Korea	21,193.6	49,523.4	495.2	1031.7	30.3	32.6	7.33
Malaysia	11,869.5	45,476.7	663.1	1895.7	40.6	57.8	11.84
Thailand	10,619.5	25,006.8	190.3	403.3	17.4	40.7	7.40
SSA*	2152.7	5264.2	4.7	8.2	18.8	16.3	7.74
East Asia	130,715.7	444,980.2	83.1	242.1	30.7	43.0	10.75
Latin America	25,063.2	103,883.3	57.9	197.9	26.7	33.6	12.58

Note: Equipment imports exclude transport equipment, but include parts and components (including those for assembly for export. SSA* means Sub-Saharan Africa excluding South Africa.

Source: Calculated from United Nations COMTRADE Database and World Bank, *World Development Indicators*, various years

The low level of equipment imports into the sample countries may seem surprising in that none of them now has any restrictions on such imports and imposes low or zero tariffs on them. The intensification of import competition, in other words, suggests not the lack of a suitable policy setting for technology upgrading but the absence of capabilities to *use* new technologies at competitive levels. Firms apparently invest little in new embodied technology because they realise that they do not have the skills, technical knowledge and other capabilities to use it efficiently in open markets. This is confirmed by several firm studies.[4]

4.2 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, 1988–2003

	Inflows ($USm)		*Inflows (shares)*	
	1988–1993 annual average	*2003*	*1988–1993*	*2003*
World	190,629	559,576	100.0	100.0
Developed countries	140,088	366,573	73.5	65.5
Developing countries	46,919	172,033	24.6	30.7
North Africa	1388	5784	0.7	1.0
Sub-Saharan Africa	2084	9250	1.1	1.7
Latin America, Caribbean	13,136	49,722	6.9	8.9
South and East Asia	27,113	96,915	14.2	17.3
Least Developed (43)	1361	7356	0.7	1.3

Source: UNCTAD (2004)

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 Republic of	0	0	0	0	0	0

Table 5 FDI Inflows into Sub-Saharan African Countries, 1987–1998 (period averages and changes on previous period, $ million) (continued)

	Period averages			*Changes*		
Country	*1987 –1990*	*1991 –1994*	*1995 –1998*	*1987 –1990*	*1991 –1994*	*1995 –1998*
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

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 1991–1994). 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 1992–1996, 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 1995–1998 varies between a high of $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.*

4.3 Technology licensing

As far as licence payments are concerned, patchy data from UNCTAD show that SSA excluding South Africa paid $US84 million in 1997 for imported technology, a tiny 1.5% of the amount spent by the developing world. Of this amount, Kenya accounted for $US39 million and Swaziland for another $39 million, and South Africa alone spent $US258 million. In the same year, by comparison, Thailand spent $US813 million, India $US150 million and China $US543 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, 1999a). 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,[6] but they are the only data available on a comparative basis.

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

Table 6 Tertiary enrolments in total and technical subjects, 1995–1997

	Three level enrolment		*Technical enrolments at three level*							
	No. of students thousands	*Percentage of population*	*Natural science*		*Math's, computing*		*Engineering*		*Total technical subjects*	
			Numbers	*Percent*	*Numbers*	*Percent*	*Numbers*	*Percent*	*Numbers*	*Percent*
Sub-Saharan Africa										
Ghana	9600	0.055	1200	0.007	200	0.001	700	0.004	2100	0.012
Kenya	31 300	0.115	3600	0.013			1000	0.004	4600	0.017
Tanzania	12 800	0.043	800	0.003	100	0.000	2700	0.009	3600	0.012
Uganda	27 600	0.140	800	0.004	300	0.002	1500	0.008	2600	0.013
Zimbabwe	45 600	0.408	2200	0.020	800	0.007	6700	0.060	9700	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	8800	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	8800	0.044	4600	0.023	12 700	0.063	26 100	0.130
Sri Lanka	63 700	0.355	8100	0.045	300	0.002	6800	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 (1999), national sources.

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 commonly used for this purpose is formal R&D. While formal R&D may not be an ideal proxy for technological effort, there is some justification for using this measure: R&D becomes important for technology absorption and adaptation in industrialising countries, even if they do not innovate as they industrialise. 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, 1989).

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 none of the five case study countries spend significant amounts on formal R&D. 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 is provided by recent studies.[7] 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, 1999; 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.

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 (percentage of distribution)*		*Source of financing (percentage of GNP)*	
	Per mill. population	*Numbers*	*(percentage of GNP)*	*Productive sector*	*Higher education*	*Productive enterprises*	*Government*	*Productive enterprises*	*Productive sector*
Industrialised market economies (b)	1102	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 (excluding South Africa)	83	3193	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 and 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)	2121	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)	1304	4 684 700	0.92	36.6	24.7	34.5	53.2	0.318	0.337

Notes: a) Only including countries with data, and with over one million inhabitants in 1995.
b) USA, Canada, West Europe, Japan, Australia and New 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
Source: Calculated from UNESCO (1999)

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, interterritorial research institutions set up by the colonial administrators to cater to the needs of the whole region handled the organisation of research. This was the case of West as well as East Africa (Lall and Pietrobelli, 2002). Let us consider some of the main technology institutions.

7.1 The Metrology, Standards, Testing and Quality (MSTQ) infrastructure

MSTQ institutions form 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 recognised standards and their certification by internationally accredited bodies is increasingly demanded in world trade. Standards can reduce transaction costs and information asymmetries between the seller and the buyer, and so minimise uncertainties with respect to quality and technical characteristics. Metrology (the science of measurement) 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 uses of technologies. Therefore, standards contribute importantly 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 interfirm 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 and retailers, as well as transnational corporations seeking local partners and subcontractors. In the whole of Africa (including Northern Africa), only 23 such institutions were operating at the end of 2000.[8]

In this section, we present evidence on standards institutions in the case study countries.[9]

7.1.1 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, 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% is spent in staff training. Furthermore, no funding is available for any kind of R&D. Total revenues amounted to about $US2.2 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% of total revenues. The lack of funds also accounts for the old and outdated equipment used in some divisions.

Table 8 Summary financial indicators of the Ghana Standards Board

	1994–1995	*1998–1999*
Revenues		
Revenues in $US million *	1.46	2.25
Sources of revenues (%)		
From government scheduled	90	82
From services sold	10	18
Expenditures (%)		
Salaries	60	77
Materials and buildings	4.5	6.6
Training	1	2
Equipment	10	5
R&D	–	–
Others	24.5	9.4
Total	100.0	100.0

Note: * Approximate figures due to variable exchange rate
Source: Interviews of GSB staff, January 2000

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 an 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 subregion of Africa.[10]

Of a total staff of 403, the administrative divisions account for 250, which is 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.

7.1.2 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 nongovernment and nonprofit 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% 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.[11] 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 its internal assessors had certified around 20 companies. However, its promotion of ISO 9000 was not very forceful. No financial assistance was offered to firms, even to SMEs, to undergo the cost of getting consultancy services, training and equipment for this purpose.[12] Industry was complimentary about the quality of testing services offered by SAZ, but much of this was used by large companies. SAZ seemed to have good 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 industrialising 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 of a crucial infrastructure body.

7.1.3 Kenya

The Kenya Bureau of Standards (KEBS) was set up in 1974 and by the end of 1999 had developed around 2000 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 ten 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 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% of ex-factory sales up to a ceiling of $US4000 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 more of 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 KEBS standards 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.

7.1.4 Tanzania

The Tanzania Bureau of Standards (TBS) 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% 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.

7.1.5 Uganda

The Uganda National Bureau of Standards (UNBS) became operational in 1989, later than most counterparts in the African region.[13] Strengthening the UNBS had been a key government priority for the period 1994–1999:

> "…. to prepare the necessary standards, to develop policy directives on standardization, to ensure the application of these standards and to create a quality and standardization awareness in all sectors of the economy, will be a key priority in implementing industrialization and export promotion policies" (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 $US1 million per year to the institution but had disbursed less than 70% of this sum. The budget of UNBS was thus considerably smaller than those 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.

7.2 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 $US10 million (the government contributing 30%). 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 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).[14]

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 underfunded 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).

The East African Community (EAC), as a regional project to promote research in industry, conceived of UIRI in the 1970s. During the days of the EAC, industrial research used to be conducted by the East African Industrial Research Organisation based in Nairobi. In 1974–1975, 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 breakup 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 received an interest-free loan of $US6 million from China. China also gave an additional $US3.6 million for laboratory and office equipment, workshops, generators and technical assistance.

By the end of 1999, UIRI employed 35 people, two 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 ($US250,000 in 1998–1999), with most of the Institute's budget used to pay salaries (35%), and materials, utilities, buildings and equipment (over 50%). Only 10% of the institution's resources went into R&D, which essentially consisted 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 for research or development.[15] 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 technology 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 the end of 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 liberalisation 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 for technology projects by industry[16] 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.

In 1998–1999, 58% of the TIRDO budget came from services sold to industry, with the remainder coming from the government budget. Owing 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% 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 1979–1996 (the small number of projects over the 27 years is itself noteworthy). The authors found that most projects were undertaken at the initiative of TIRDO 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.

In *Kenya*, 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.[17] KIRDI was placed under a new director, who redefined its work to move from R&D to *industrial technology support* and reorganised the institution.[18] 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 microenterprises and has participated in a World Bank-financed project on technical services to microenterprises. 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 reform, all the six centres in KIRDI offer consultancy services, and are allowed to retain all their earnings except for costs and a 15% overhead.

In *Zimbabwe*, despite its large manufacturing sector and reasonable base of industrial capabilities (Lall, 1999b),[19] there were no public R&D institutions in manufacturing technology till the end of the 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, liberalisation 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 under the President's office.[20] At the time of visiting this Centre (authors' field visit in 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 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,p.43). In 1999, the IRI received about $US370,000 from the government, of which only 5% 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 of reaching 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 underfunded, 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, the most active (and well-funded) ones have focused on agriculture rather than manufacturing. Industrial R&D institutes have done poorly, failing to offset (and, indeed, 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, though its current economic and political malaise may well thwart the attempt to improve its innovation capabilities.

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

Their poor performance reflects not just internal constraints but also technological apathy in much of local industry. Most enterprises are not technologically active and aware; few have responded to liberalisation by mounting technology-upgrading strategies. Given this, it is very difficult for R&D institutions to provide effective assistance (Rush *et al*., 1996). Governments have not given priority to promoting industrial research, in enterprises or public institutions. This has reinforced the general feeling of marginalisation and discouragement in most institutions.

To conclude on technology institutions, the picture of national technology systems that emerges from this sample is discouraging. It is likely that this picture is representative of the SSA region (with the clear exception of South Africa). All the main elements of the system are weak. The technology infrastructure is small, passive and largely ineffective. It is often poorly funded and poorly motivated and 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 liberalisation. 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.[21] 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 industrialised successfully, as in Asia or Latin America, have developed a 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 industrialising economies are 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 on policy

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 liberalisation 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, 2002; 2004; 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 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 liberalisation 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 industrialising countries in East Asia, there has been little attention given to the technology system. Even 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 coordinating and planning the technology system.

8.1 Technology strategy formulation

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 overambitious 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.

8.2 Coordinating and planning the technology system

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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References

Abramovitz, M. (1986) 'Catching up, forging ahead, and falling behind', *Journal of Economic History*, June, Vol. 46, No. 2, pp.385–406.

Amsden, A.H. (2000) *The Rise of the Rest: Late Industrialization Outside the North Atlantic Region*, New York: Oxford University Press.

Berry, A. and Escandon, J. (1994) 'Colombia's small and medium-sized exporters and their technology systems', *Policy Research Department Working Paper*, Washington, DC: The World Bank, No. 1401.

Biggs, T., Shah, M. and Srivastava, P. (1995) 'Technological capabilities and learning in African enterprises', *World Bank Technical Paper*, Washington, DC: World Bank, No. 288.

Bongenaar, B. and Szirmai, A. (2000) 'Development and diffusion of technology, the case if TIRDO', in A. Szirmai and P. Lapperre (Eds.) *The Industrial Experience of Tanzania: A Case Study of Industrialisation in Sub-Saharan Africa*, London: Macmillan.

Cassiolato, J.E., Lastres, H.M.M. and Maciel, M.L. (Eds.) (2003) *Systems of Innovation and Development. Evidence from Brazil*, Aldershot: Edward Elgar.

Cohen, W.M. and Levinthal, D.A. (1989) 'Innovation and learning: the two faces of R&D', *Economic Journal*, Vol. 99, No. 4, pp.569–596.

Collier, P. and Gunning, J.W. (1999) 'Why has Africa grown slowly?', *Journal of Economic Perspectives*, Vol. 13, No. 2, pp.3–22.

Council for Scientific and Industrial Research (CSIR) (1999) *CSIR Handbook*, Accra, Ghana.

Edquist, C. (Ed.) (1997) *Systems of Innovation: Technologies, Institutions and Organisations*, London: Pinter.

Edquist, C. and McKelvey, M. (Eds.) (2000) *Systems of Innovation: Growth, Competitiveness and Employment*, Cheltenham: Edward Elgar, Vol. 2.

Enos, J.L. (1995) *The Pursuit of Science and Technology in Sub-Saharan Africa Under Structural Adjustment*, London: Routledge.

Ernst, D. and Lundvall, B.Å. (1997) 'Information technology in the learning economy. Challenges for developing countries', *DRUID Working Paper, No. 1997–12*.

Freeman, C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*, London: Frances Pinter.

Freeman, C. (1995) 'The "National System of Innovation" in historical perspective', *Cambridge Journal of Economics*, Vol. 19, No. 1, pp.5–24.

Gibbon, P. (2003) 'The African growth and opportunity act and the global commodity chain for clothing', *World Development*, Vol. 31, No. 11, pp.1809–1827.

Guerrieri, P., Iammarino, S. and Pietrobelli, C. (2001) *The Global Challenge to Industrial Districts: SMEs in Italy and Taiwan*, Cheltenham: Edward Elgar.

Lall, S. (1992) 'Technological capabilities and industrialization', *World Development*, Vol. 20, No. 2, pp.165–186.

Lall, S. (1996) *Learning from the Asian Tigers: Studies in Technology and Industrial Policy*, London: Macmillan.

Lall, S. (1999a) 'Competing with labour: skills and competitiveness in developing countries', *Issues in Development, Working Paper*, Geneva: ILO, No. 31.

Lall, S. (Ed.) (1999b) *The Technological Response to Import Liberalization in Sub-Saharan Africa*, London: Macmillan.

Lall, S. (2000) 'The technological structure and performance of developing country manufactured exports, 1985–1998', *Oxford Development Studies*, Vol. 28, No. 3, pp.337–369.

Lall, S. (2001) *Competitiveness, Technology and Skills*, Cheltenham: Edward Elgar.

Lall, S. and Pietrobelli, C. (2002) *Failing to Compete: Technology Development and Technology Systems in Africa*, Cheltenham: Edward Elgar.

Lall, S. and Wangwe, S. (1998) 'Industrial policy and industrialisation in Sub-Saharan Africa', *Journal of African Economies*, Supplement, Vol. 7, No. 1, pp.70–107.

Lall, S. and Wignaraja, G. (1998) 'Mauritius: dynamising export competitiveness', *Commonwealth Secretariat, Economic Paper*, London: No. 33.

Lall, S., Barba-Navaretti, G., Teitel, S. and Wignaraja, G. (1994) *Technology and Enterprise Development: Ghana under Structural Adjustment*, London: Macmillan.

Lall, S., Robinson, P. and Wignaraja, G. (1998) 'Zimbabwe: enhancing export competitiveness', *Study for the Ministry of Industry, Zimbabwe, and the Commonwealth Secretariat*, London.

Lastres, H.M.M. (2003) 'Systems of innovation and development', *Paper Presented at the 1st Globelics Conference*, Rio de Janeiro, November.

Latsch, W. and Robinson, P. (1999) *Technology and Responses of Firms to Adjustment in Zimbabwe*, in S. Lall (Ed.).

Levy, B., Berry, A., Itoh, M., Kim, L., Nugent, J. and Urata, S. (1994) 'Technical and marketing support systems for successful small and medium-sized enterprises in four countries', *Policy Research Department Working Paper*, Washington, DC: World Bank, No. 1400.

List, F. (1841) *The National System of Political Economy*, English edition (1904), London: Longman.

Lundvall, B.Å. (Ed.) (1992) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.

McKelvey, M. (1991) 'How do national systems of innovation differ', in G. Hodgson and E. Screpanti (Eds.) *Rethinking Economics*, Aldershot: Edward Elgar.

Metcalfe, J.S. (1995) 'Technology systems and technology policy in an evolutionary framework', *Cambridge Journal of Economics*, Vol. 19, No. 1, pp.25–46.

Ministry of Trade and Industry (MOTI) (1994) *Uganda Industrialisation Policy and Framework 1994–1999*, Kampala, Uganda.

Nelson, R.R. (Ed.) (1993) *National Innovation Systems: A Comparative Analysis*, New York: Oxford University Press.

Nelson, R.R. and Winter, S.J. (1982) *An Evolutionary Theory of Economic Change*, Cambridge, Massachusetts: Harvard University Press.

Pietrobelli, C. (1997) 'On the theory of technological capabilities and developing countries' dynamic comparative advantage in manufactures', *Rivista Internazionale di Scienze Economiche e Commerciali*, June, Vol. XLIV, No. 2, pp.313–338.

Pietrobelli, C. (1999) *Industry, Competitiveness and Technological Capabilities in Chile: A New Tiger from Latin America?*, London: Macmillan.

Pigato, M. (1999) 'Foreign direct investment in Africa: old tales and new evidence', *World Bank*, Africa Region, Draft.

Rush, H., Hobday, M., Bessant, J., Arnold, E. and Murray, R. (1996) *Technology Institutes: Strategies for Best Practice*, London: International Thomson Business Press.

Standards Association of Zimbabwe (SAZ) (1997) *Annual Report 1995–1996*, Harare: SAZ.

United Nations Conference on Trade and Development (UNCTAD) (1998) *Foreign Direct Investment in Africa: Performance and Potential*, UNCTAD/ITE/Misc.5, Geneva.

United Nations Educational, Scientific and Cultural Organization (UNESCO) (1999) *Statistical Yearbook*, Paris: United Nations.

United Nations Industrial Development Organization (UNIDO) (2002) *Industrial Development Report 2002–2003*, Vienna.

United Nations Industrial Development Organization (UNIDO) (2004) *Industrial Development Report 2004: Industrialization, Environment and the Millennium Development Goals in Sub-Saharan Africa*, Vienna.

Wangwe, S.M. (1995) *Exporting Africa: Technology, Trade and Industrialisation in Sub-Saharan Africa*, London: Routledge.

Wangwe, S.M. and Diyamett, B. (1998) 'Cooperation between R&D institutions and enterprises: the case of the United Republic of Tanzania', *New Approaches to Science and Technology Cooperation and Capacity Building*, Geneva: UNCTAD, pp.193–210.

Wignaraja, G. (1998) *Technological Capabilities and Industrialization. The Case of Sri Lanka*, London: Macmillan.

Wignaraja, G. and Ikiara, G. (1999) 'Adjustment, technological capabilities and enterprise dynamics in Kenya', in S. Lall (Ed.) *The Technological Response to Import Liberalization in Sub-Saharan Africa*, London: Macmillan, pp.57–111.

World Bank (1994) *Adjustment in Africa: Reforms, Results, and the Road Ahead*, Washington, DC: The World Bank.

World Bank (2004) *World Development Indicators*, Washington, DC.

Bibliography

Archibugi, D. and Pietrobelli, C. (2003) 'The globalisation of technology and its implications for developing countries: windows of opportunity or further burden?', *Technological Forecasting and Social Change*, Vol. 70, pp.861–883.

Battisti, G. and Pietrobelli, C. (2000) 'Intra-industry gaps in technology and investments in technological capabilities: firm-level evidence from Chile', *International Review of Applied Economics*, Vol. 14, No. 2, pp.253–269.

Biggs, T. and Srivastava, P. (1996) 'Structural aspects of manufacturing in Sub-Saharan Africa', *World Bank Discussion Papers*, Africa Technical Department Series, No. 346.

Bwisa, H.M. and Gacuhi, A.R. (1997) 'Diffusion and adaptation of technology from research institutes and universities in Kenya: an empirical investigation', *Nairobi: African Technology Policy Studies, ATPS Policy Brief.*

Gogo, J.O. (2000) 'Policies for technology transfer: Ghana', *Paper Prepared for UNCTAD*, Accra, May.

Gogo, J.O., Micah, J.A., Afful, K.N. and Goka, A.M. (1998) 'The development and management of science and technology policy in Ghana', *Final Report on Phase 1 of the Carnegie Project on S&T Policy Dialogue*, New York: Carnegie Corporation, February.

International Organization for Standardization (ISO) (2000) *The ISO Survey of ISO 9000 and ISO 14000 Certificates – Ninth Cycle*, The International Organization for Standardization, Geneva, http://www.iso.ch

Kingoria, G.K. and Gacuhi, A.R. (1999) 'Basic sciences for the development of Kenya', *Nairobi: NCST and Ministry of Research and Technology, Prepared for the Conference of Basic Sciences for Development in Eastern and Southern Africa*, Draft.

Lall, S. (1998) 'Exports of manufactures by developing countries: emerging patterns of trade and location', *Oxford Review of Economic Policy*, Vol. 11, No. 2, pp.54–73.

Lall, S. and Pietrobelli, C. (2003) ‘Manufacturing in Sub-Saharan Africa and the need of a National Technology System’, in M. Muchie, B.Å. Lundvall and P. Gammeltoft (Eds.) *The Making of African Innovation Systems,* Aalborg University Press, http://www.globelics.org/index.php?module=htmlpages&func=display&pid=3

Ocampo, J.A., Zamagni, S., Ffrench-Davis, R. and Pietrobelli, C. (Eds.) (2000) *The Globalization of Financial Markets and the Emerging Economies*, Santiago: ECLAC http://www.eclac.cl/English/books/lcg2097/index.htm

Organization for Economic Cooperation and Development (OECD) (1997) *National Innovation Systems*, Paris.

Pietrobelli, C. (1994) ‘Technological capabilities at the national level: an international comparison of manufacturing export performances’, *Development Policy Review*, Vol. 12, No. 2, pp.115–148.

Pietrobelli, C. (1996) ‘Emerging forms of technological co-operation: the case for technology partnerships – inner logic’, *Examples and Enabling Environment*, Science and Technology Issues, Geneva: UNCTAD.

Pietrobelli, C. (2000) ‘The role of international technology transfer in the industrialization of developing countries’, in M. Elena and D. Schroeer (Eds.) *Technology Transfer*, Aldershot: Ashgate.

Sverrisson, A. (1993) *Evolutionary Technical Change and Flexible Mechanisation: Entrepreneurship and Industrialisation in Kenya and Zimbabwe*, Lund: Lund University Press.

United Nations Conference on Trade and Development (UNCTAD) (1998) *Survey of Foreign Firms in Uganda*, Kampala: InterAfrica Corporate Ltd. for UNCTAD and UIA.

United Nations Conference on Trade and Development (UNCTAD) (1999) *Foreign Direct Investment in Africa: Performance and Potential*, New York and Geneva: United Nations, Sales No. E.98.II.D.5.

United Nations Conference on Trade and Development (UNCTAD) (various years) *World Investment Report*, United Nations, Geneva.

Wangwe, S.M., Musonda, F.M. and Kweka, J.P. (1997) ‘Policies for manufacturing competitiveness: the case of Tanzania’, *Dar es Salaam: Economic and Social Research Foundation*.

Notes

1 Of the large and growing literature on this subject see Freeman (1987; 1995), Lundvall (1992), McKelvey (1991), Metcalfe (1995), Nelson (1993), Edquist (1997) and Edquist and McKelvey (2000). These interactions are *systemic* in the sense that the same elements recur in all economies and have a coherent set of predictable interactions.

2 See for instance, chapters in Nelson (1993), Ernst and Lundvall (1997) and recently Cassiolato *et al.* (2003), Lastres (2003) and papers presented at *Globelics* meetings (www.globelics.org).

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

4 For an up-to-date assessment see UNIDO (2004).

5 See for example on Sub-Saharan Africa Biggs *et al*. (1995), Lall *et al.* (1994), Lall (1999b), and Wangwe (1995).

6 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. Note that more up-to-date data on the breakdown of tertiary education are not available from UNESCO.

7 See Biggs *et al*. (1995), Lall *et al.* (1994), Lall (1999b) and Wangwe (1995).

8 http://www.iso9000.org

9 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.

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

11 Authors' field visit in 1997, Lall *et al.* (1998) and Lall and Pietrobelli (2002).

12 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 *et al.*, 1998).

13 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 Cooperation.

14 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.

15 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 ($US1.4 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 $US160,000).

16 The only exception mentioned was the development of particle-board 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.

17 See Lall and Pietrobelli (2002) for details.

18 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.

19 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, 1999b). 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 (1999b) 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.

20 The seven research institutes planned in Zimbabwe are:

1 Biotechnology Research Institute

This institute, with five divisions, will work on such projects as the development of drought-resistant maize species, micropropagation of disease-resistant potatoes and food irradiation.

2 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.

3 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.

4 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 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 troubleshooting 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*.

5 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.

6 Energy Technology Institute

This will work on energy conservation, nonconventional sources of energy and efficient generation from conventional sources.

7 National Metrology Institute

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

21 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).