

Human Capital Development Programme for Effective ICT in Africa

Framework Paper for the AERC Project on ICT Policy and Economic Development in Africa

By Nimal Nissanke

“Human resource development is a crucial requirement not only to build up technical knowledge and capabilities, but also to create new values to help individuals and nations cope with rapidly changing social, environmental and development realities.” – World Commission on Environment and Development, [33]

1. Introduction

Over the last three decades or so, Africa’s performance in economic growth and development has been below expectations and raises serious concerns about its prospects relative to other developing regions such as East Asia, South East Asia, Latin America and, more recently, South Asia. Though the growth performance in many African countries has picked up over the last several years, largely due to the commodity booms, there are serious doubts as to whether the growth dependent on natural resources boom is sustainable over the long term, especially for creating a path towards broad-based economic development, and whether it can play a role of an effective conduit for fundamental transformation of structures of African economies. Among other conditions, Africa’s huge handicap in taking advantage of the worldwide ICT revolution requires a particular attention in considering Africa’s future in the global economy. So far, the uneven spread of ICT seems to underline and sharpen the disparities between Africa and the rest of the world, particularly the developed world. Yet, the very same ICT, the great ‘leveller’ between ‘haves’ and ‘have-nots’, provides a unique opportunity for Africa to break away from this vicious cycle, following a path similar to that taken by the vibrant new economies in Asia and Latin America. A prerequisite for making this a reality, however, lies not directly in her traditional strength in natural resources but in her untapped, potentially significant, human resources. This paper attempts to identify the challenges faced by Africa in terms of her human resources in exploiting ICT into her economic advantage and explores how best to bring about Africa’s human resources capability in ICT to a competitive level that is in line with world standards.

Compared to its current achievements, there is significant further scope for Africa to benefit from ICT. For the purpose of our discussion, we distinguish between two aspects of ICT: on the one hand, reliance on ICT applications for efficiency gains and, on the other, the production of ICT goods for the internal market and export. Dealing with the former first, from a utilitarian point of view, the use of ICT applications in industry, commerce, agriculture and public administration could bring about, as in the developed and many other developing countries, significant efficiencies, improved quality of service in areas such as health and education, better quality of life for citizens, enhanced and new market opportunities for entrepreneurs and so on. These may take numerous forms, benefiting, amongst others, rural communities through marketing and financial services and producers of developing countries through new global markets for their business, etc. A fuller account of different benefits may be found in [6]. These could in turn generate new businesses and new and better

employment prospects for all. A complementary way to exploit ICT as a vehicle for economic development is to invest in the production of ICT goods with the specific aim of entering the ICT producing market, in particular, in areas such as software development and assembly and manufacturing of computing equipment and components. Though initially they may be limited to meeting the internal demand, such efforts may offer, in the longer term, opportunities for export and outsourced technological processes.

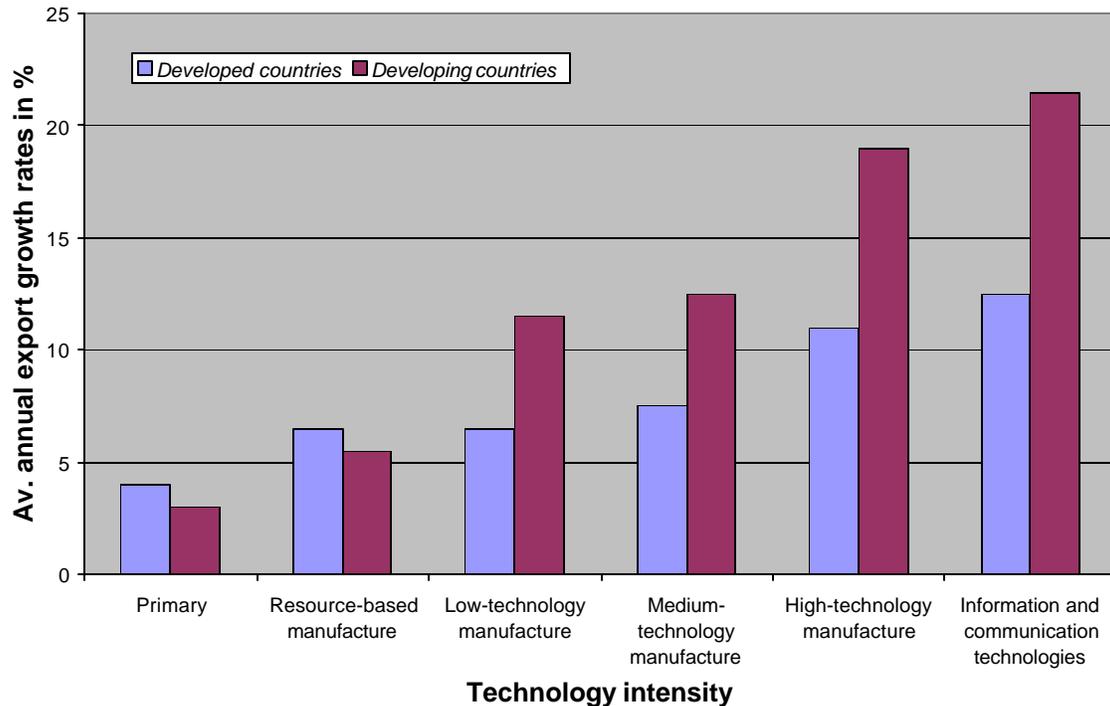


Figure 1. Significance of ICT on Export Growth (Annual Growth Rates of World Exports by Technology Intensity 1985-2000; Source: UNCTAD World Investment Report 2002)

Out of the above two possible paths, competent use of ICT applications is undoubtedly the most immediate way of benefiting from ICT regardless of the state of development of a given economy. In the case of most African developing countries, its significance to economic development could outweigh the benefits that could be drawn from the production of ICT goods. However, the importance of efforts directed at the production of ICT goods is not to be underestimated. As evident from the information given in Figure 1, the developing countries appear to enjoy generally significantly higher growth rates in ICT exports, compared to other export-oriented economic sectors. This suggests that such efforts could offer, at least for some African countries, long-term strategic advantage in turning their economies into modern knowledge-based economies.

The attainment of such a goal, however, requires careful planning since an all-out massive investment in high-tech industries is economically unsustainable for any developing country. One promising avenue, however, is to target any investment capacity available at strategically chosen market niches. In this respect, by virtue of its special characteristics as manifested in today's global economy, the software industry offers an unusual opportunity to all developing countries [15], as that enjoyed by countries such as India and China [28], [30]. Firstly, thanks to its knowledge-intensive nature and relative independence from the hardware manufacturing industry, compared to other high-tech industries the software industry requires relatively much less capital expenditure on equipment and, instead, shifts the emphasis predominantly towards human capital. Secondly, increasing reliance of

commercial and industrial enterprises on the Internet as a ubiquitous communication medium to globalise their operational activities is creating a worldwide market for software development. Thirdly, due to high labour costs in the developed world the software industry is experiencing, as no other industry, increasing pressure to look towards low-wage, but technologically capable, countries to fill the gaps in its capability that it cannot fill locally in the developed countries. Not only do these factors open the software industry to worldwide competition but also make it possible for developing countries to compete successfully. The key ingredient for success, however, is the availability of sufficiently well-developed human resources. African countries aiming to cash in on this opportunity have to take, bearing in mind the current state of their human capital, urgent and imaginative steps to upgrade its ICT workforce to the necessary professional standard in order to quickly and effectively respond to this emerging demand.

The broad thrust of an approach as the one outlined above could be used to transform the economies in the developing world, including those in the African continent. It offers a unique opportunity to break away from the traditional mould of international trade as a supplier of raw materials and low-cost labour intensive goods. In addition, it could be used as a stepping-stone to leap-frog certain phases of industrialisation underwent by the developed world in the development process. The viability of this approach has already been demonstrated, to an extent, by countries such as India, Brazil and, interestingly, Costa Rica; see Section 6.2.2 on India and Section 6.2.3 of this paper and §2.3.1 of [6] on ICT for Economic Opportunity for Costa Rica's endeavour to become an exporter of software products and services. Unlike in the case of many other developing countries, however, African developing countries rich in natural resources possess a special advantage to make this happen quickly by exploiting the revenues of the currently buoyant commodity market to rapidly create the required technological and human resource capability almost with no, or considerably less, external financial input.

Following such a path, Africa would be able to play a balanced role in ICT as a partner on an equal footing with other countries so that it could fully benefit from ICT, not merely as a consumer but also a producer, and that it will be in a strong position to shape the future development of ICT, paying particular attention, in the African context, to its specific socio-economic goals and long-term sustainability. Therefore, it is vital that African countries adopt forward-looking long-term ICT policies as a matter of urgency.

As we examine possible paths for ICT development in Africa, it is instructive to position Africa and other developing countries with similar economic backgrounds in the ladder of the historical phases that the developed world had gone through in its ICT development. Particularly in Western countries, the ICT development took place in several relatively easily identifiable phases [29] with following characteristics

- a) Early adopters and primitive tools (1951-1962)
- b) Regulated environment and frustrated users (1963-1974)
- c) End user computing and decentralisation (1975-1984)
- d) IT as a competitive strength (1985-1995)
- e) e-Commerce and ubiquitous (anywhere-anytime) computing (1996 - to the present)

This historical perspective provides Africa (and other developing countries concerned) with a basis for developing a strategy for the development of its ICT. Though the early phases can be skipped to an extent, Africa needs to adopt (d) as its immediate goal in relation to all her economic activities, industry, agriculture, social services and government administration, and (e) as some of the key areas where early demonstration of local competence may help Africa, in due course, to project an image of a region with high ICT capability; see [10], [30] for some of the policy issues involved in relation to

e-commerce. This does not, however, imply that the early phases of Western ICT development can be entirely ignored. This is the era when the developed world put in place some of the core institutional structures (see Section 4.3) required for facilitating, as well as regulating, the development of ICT. Africa needs to go through the same exercise quickly. Having the benefit of the Western historical experience, as well as the Far Eastern experience now, Africa is in advantageous position to accomplish this task more effectively and in time for the African ICT to have the necessary credentials, though exercising care in adapting the institutional structures from other countries to prevent being “locked into a mode of knowledge production ... less relevant to their specific technological and economic requirements” [15] (§3.2).

The aim of this paper is to explore how to develop a strategy for rapid upgrading of human resources capability in Africa in ICT so that it is better placed to exploit the unfolding worldwide ICT revolution to its economic advantage and to use it as an impetus to drive the countries in the continent on a path to becoming knowledge-based economies. The paper will examine the role of human capital in Africa in technological capability building in Africa from the point of ICT, how well it is equipped currently to play such a role, and what needs to be done to improve the state of affairs in human capital development in ICT. The latter involves a setting up of a framework for undertaking a detailed study of human resources capability of a selection of African countries in ICT based on a more ICT-specific set of criteria than those used in most studies devoted to assessing the state of human capital. It is hoped that such a study would enable the formulation of strategies and policies based on accurate information on ground on how to go about in raising Africa’s human capital in ICT to a high standard.

The study of the human capital development for ICT in Africa involves several important issues. Broadly speaking, they concern the roles of governments, educational establishments and private enterprises in developing the technological and human resources capabilities in order to bring about, and support, greater use, and exploitation, of ICT for economic development. A proper appreciation of these issues requires some understanding of the core ideas in technological capability building with special reference to ICT, indicators for measuring the technological and ICT capability, and the means of its achievement, particularly with reference to human capital. The indicators mentioned are essential because without them there are no means to ensure the achievement of technological capability to a level sufficient to bring about an ICT-driven knowledge-based economy.

In discussing these issues, the remaining part of the paper is structured as follows. Section 2 introduces the roles of knowledge, technology and information in a modern economy and highlights how any deficiencies in them can be used to gauge what needs to be accomplished. Section 3 is an overview of different aspects of technology capability. Its aim is to highlight, rather than to give a detail account about, what specific capabilities constitute technology capability, the place of human resource capability in this context, the roles and the means of technology and knowledge transfer in its realisation, and the role of governments. Section 4 discusses various mechanisms of technology and knowledge transfer. Section 5 is a discussion of some of the indicators used in current practice by different agencies and researchers to measure technology capability and the attainment of the required human capital stock. Based on widely available sources of data, Section 6 points out the challenges facing African countries in terms of technological capability and human capital and inspires possible ways forward for Africa by examining the experiences of three countries, newly industrialised Singapore, and India and Costa Rica – two of the recent success stories in the developing world in tapping ICT for economic development. Section 7 outlines the predominant means of human capital development. Section 8 suggests a framework for assessing human capital development requirements for ICT development as part of the proposed country research. Section 9 concludes the paper with a summary, as well as certain policy options and required actions for capability and human resource development in Africa.

2. Information and Technology in Knowledge-driven Economies

As never before, modern economies are characterised by the knowledge-based intangible assets in the production of goods and services and in their trade. This becomes even more pronounced in today's society, which is undergoing sweeping changes under the twin forces of globalisation and the technological revolution taking place in the areas of information processing and telecommunications. In addition to bringing in efficiencies in manufacturing and commerce, the information age has given rise to intangible 'goods', hitherto unknown in international trade, and services provided over the Internet unrestrained by the usual natural barriers to trade. A by-product of this virtually borderless marketplace with no international time zones has been the intense competition, on the one hand, forcing innovation and, on the other, multiplying the opportunities open to all and making them equitable, at least in theory. How these processes operate in practice, however, is different. They let the stronger and the richer to become even more so, often marginalising, or at the expense of, the weaker and the poorer. Dividing the world into a three-tier global divide, namely, innovators, adopters and those practically excluded from the technological advancement, Sachs and McArthur [25] show how the latter tend to fall continually behind the other two groups, while the adopters in East Asia, during certain periods in the past, even performed better than the leaders of technology. The challenge is to alter this state of affairs in a way that the weak and the poor have a truly equitable share of the benefits that the globalisation and the increasingly knowledge-based, ICT propelled, economies are capable of bringing about. An essential ingredient in such an endeavour is to raise the education at all levels and, through it, to bring about a competent workforce capable of making the best use of ICT to economic advantage of the developing countries, particularly, in Africa.

2.1. Knowledge, Technology and Information

Such a development strategy requires a clear understanding of how such economies operate. Any knowledge-based economy rests on three pillars: 'knowledge', 'information' and 'technology'. These are terms which lack precise meanings. 'Knowledge' in particular has philosophical and epistemological underpinnings. As understood here, however, 'knowledge' refers to the scientific and technical knowledge in areas such as computer science, information technology, engineering and manufacturing. It enables us to understand our surroundings, the environment and the laws governing its evolution, materials and other substances, their behaviour and possible uses, and so on. The term 'technology' refers to the means and the processes used in the application of scientific and technical knowledge to improve or modify our natural environment, or to innovate the things that we have already produced, in order to satisfy perceived materialistic human needs, from the production of things that we need and the comforts that we take for granted in our day-to-day life to taking care of our environment. Nowadays, we resort to technology inevitably with industrial or commercial objectives, paying particular attention to mass production, efficiency and cost-effectiveness.

'Information' is a term complementary to the 'knowledge' but has a distinct meaning [37]. It refers to knowledge about 'attributes' of different aspects of our material life such as the quality of a product or a service, market information such as cost and prices, the performance of a worker or a company, the facilities provided by a bank or a development agency, track record of an entrepreneur or trustworthiness of a borrower, trustworthiness of a system, safety of a plant, the state of climate, etc. This kind of information allows us to make judgements about, or critically evaluate, our material life or investment decisions, enabling us to make better and judicious choices in running plants, farms, transport, schools and government departments efficiently and smoothly, and in taking proper care of our resources and the environment. The critical evaluations, made on the basis of such actual observations, prompt the designers and developers to think of possible improvements, possibly

forcing the frontiers of knowledge forward. Thus, they serve as an internal driver for innovation in technology.

Thus, all three concepts, knowledge, information and technology, play an indispensable role in any development effort undertaken towards a knowledge-based economy. Success would depend on how well we address the ‘gaps’ in knowledge and technology and the deficiencies in available information (‘information problems’) at the same time [37]. The strengths and weaknesses of the three concepts serve as a gauge to identify how far, and in which direction, African countries have to move in order to transform their economies into knowledge-based ones.

2.2. Gaps in Knowledge

It is important to take neither the knowledge gaps nor the information problems in an absolute sense. Given the current state of development, local conditions and local priorities of most African countries, it is virtually an impossible task for them to fill the knowledge gap in an absolute sense with any developed country or, for that matter, certain developing countries such as India. This is because, on the one hand, the corpus of technical knowledge accumulated by developed countries is vast by any standard and, on the other, knowledge is not static and keeps unfolding continuously at a pace hitherto unknown in human history. It is a futile exercise for less developed African and other countries to go through the same processes of learning, discovery and innovation. Even if filling the knowledge gap in an absolute sense is possible, this is an unnecessary task. In today’s world, knowledge gaps may be filled through international educational and technological collaborations and strategic industrial alliances. Given such opportunities, what is important for African countries therefore is to set appropriate developmental goals, realistic and achievable over a given timescale and within available resources, to identify the missing gaps in knowledge, and to concentrate efforts to remedy the situation, that is, to acquire, assimilate, adapt or refine the missing, or the insufficiently developed, areas of knowledge.

2.3. Gaps in Technology

Technology and technical knowledge are inextricably linked; one cannot exist or flourish without the other. Even if the knowledge may be acquired by some means, the technology that is needed to put knowledge into good use requires funds, an infrastructure, equipment and plants, and skills. Thus, the level of technology that a country can have is determined by affordability. Therefore, given the dire economic conditions, technological backwardness of most African countries is hardly surprising. Any technology they have is often limited to basic processing of natural resources, often to a level just sufficient for export purposes. The current state of manufacturing and other technologies is well documented in [14] – a joint study by UNCTAD, WTO and International Trade Centre on four African countries: Kenya, Ghana, Uganda and Tanzania. Disjointed poor production facilities, dated plants and equipment, low productivity, low level processing and basic manufacturing activities are all too typical in the African industrial scene. Bridging its technology gap in manufacturing and other industries is perhaps one of the biggest challenges that Africa is facing. However, its technology gap in ICT may not be so alarming. The fast take up of mobile phone technology is making such an impact on Africa that at least the setting up of an advanced communication infrastructure in the near future is a possibility. Given our argument in Section 1 on the viability of software industry in developing countries with relatively low capital layout, this offers a different path to bridge the ICT technology gap in Africa.

2.4. Information Problems

Though knowledge gaps can be addressed through some form of knowledge transfer (see Section 3), the same cannot be said of information problems. This is because the bulk of the information has to be locally generated and managed, that is, gathered, analysed and synthesised, maintained and made available in a form beneficial to the interested parties. In the case of certain African countries with similar economical, cultural, geographical and other backgrounds, however, some information problems may be addressed through other means, for example, adoption of experiences of other countries, e.g., standards and norms. Generally, the kind of information of primary interest here falls into a number of different broad categories [37], including the following:

- Market information (costs, prices and suppliers of products and services)
- Research, development and experiential information (material publicised for the overall good of the economy, better public awareness or professional scrutiny; this includes, for example, the latest R&D findings, new services and facilities, new products, novel techniques, achievements and failures, lessons to be learnt from experience, etc.)
- Regulatory and normative information (information on standards, norms and good-practice, for example, information on quality of products and services, performance and norms on industries and institutions, as required by law or regulatory authorities or on grounds of good-practice)
- Performance information (information on measurements or observations, for example, on actual quality of products and services or actual performance levels of industries and institutions, as observed at plants, at institutions, on the field, etc.)

Deficiencies in information could be a serious hindrance to development. Furthermore, information could be costly and dependent on technology and, hence, asymmetrical in accessibility. Timely addressing of information problems could bring about significant economic benefits by enabling markets to function properly [37]. These benefits could be significant in the African context since they typically concern provision of reliable information on market conditions in both urban and rural environments (e.g. prices of farming equipment and farm produce), open and free access to information and, hence, facilitating more informed negotiations between buyers and suppliers to each other's competitive advantage and creating a level playing field for all those who operate in a given economic sector (e.g. manufacturers, sub-contractors, retailers, consumers, etc.); see [28] and §2.2.3 on ICT for Economic Opportunity in [6]. The same applies to attracting investments, since the local information and information about potential clients are vital for investment decision makers.

3. Knowledge and Technology Transfer

Bridging knowledge and technology gaps is essential if African countries were to succeed in exploiting ICT in its economic development. It is also clear from the aforementioned that both are interconnected and, in addition, there are other factors that are also closely linked. They all need to be addressed at the same time and is done so under, what is known as, capability development. Therefore, as this section demonstrates, there is already a wealth of experience in capability development that could be relied upon in ICT capability development.

3.1. Technological Capability Development

A common definition of technological capability (e.g. SciDev.net [26]) is the ability of a given country to make use of the knowledge to acquire, assimilate, adapt, and change existing technologies and develop new products and processes to meet development objectives. Technological capability has several dimensions of capabilities, or constituent or sub- capabilities. These are: human resources capability, process and management capability (in relation to industrial plants and processes), institutional infrastructure capability, technological infrastructure capability, and financial capability¹;

¹ These are similar to individual skills, process maturity, management capability, technology, revenue model and product marketing capability [30].

see Figure 2. However, if we are to appreciate better the goals to be achieved and the roles to be fulfilled by the agents involved in the process of its acquisition, a deeper understanding is necessary.

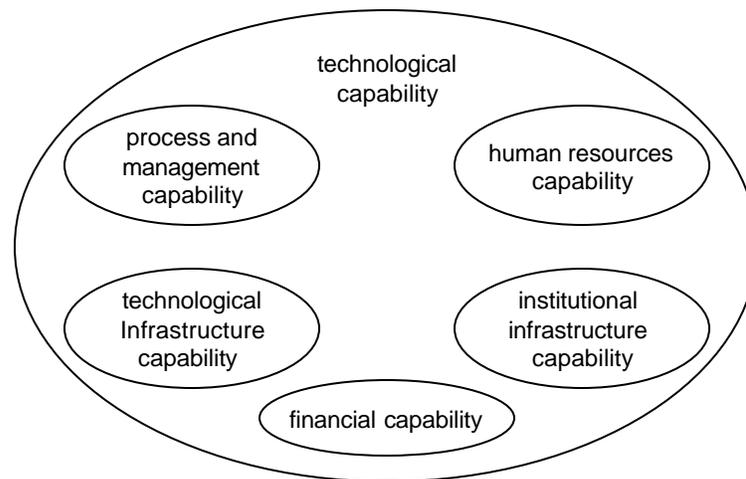


Figure 2. Constituent capabilities of technological capability

Taking an instrumental view in the form of an intermediate good, specifically as an input to an economic system enabling the more productive use of its resources, three essential aspects of technological capability can be identified [7]. Firstly, it encompasses the ability of humans to understand technical processes, acquire the knowledge about them, interpret and adapt it to suit the local conditions and apply it creatively to the solution of practical industrial problems. Secondly, it carries a strongly institutional character, implying the existence of certain specific institutions that enables the integration of technical knowledge possessed by the society as a whole into a coherent framework and thus its application in a complementary and productive manner for the benefit of the society as a whole. Thirdly, it has to be driven by a common purpose shared by the society, thus letting it draw its strength from the psychological motives and the political aspirations of the society. Though it is perhaps wrong to place extra emphasis on any single one of these elements, for all three must be in place on an equal footing if technological capability is to deliver what is expected of it, its 'institutional character' and the need of a 'common purpose' are two aspects that require special mention in the case of some African countries because of their relatively low starting economic base and, historically, the volatility of political leadership and, hence, a lack of an uninterrupted clear direction for long-term development.

3.2. Technological Capability Development in ICT Compared to Other Economic Sectors

Out of the three economic sectors applicable to developing countries, that is, a) primary sector (agriculture); b) secondary sector (industry); and c) tertiary sector (information processing as output, for example, in banking, finance, medical care, wholesale and retail trade, administration of government, education, etc.) [7], two sectors that are directly relevant to ICT development in Africa are the secondary and tertiary sectors. This is because they are characterised by their reliance on knowledge conveyed through education and training and internationally standardised techniques, rather than on knowledge passed down from generation to generation and specialised knowledge provided by various agencies and institutions as in the primary sector. Thus, the secondary and tertiary sectors shift the employment criteria to skills from family or social connections relied upon in the primary sector. Another distinction is that, unlike in the primary sector, the technological capability in the secondary sector is task-specific [7]. Tasks vary from the simplest to the more

complex, require more training on from procurement and installation of capital equipment to operation and major improvements in existing techniques, and involve closer relations with suppliers and customers. In the tertiary sector, capability has little to do with such mastery of a technology for producing goods.

In the case of African countries aiming at a greater role of ICT in the economy, the above view of economic sectors might be too restrictive. This is because depending on the nature of its role, ICT may fall into one, or both, of the secondary and the tertiary sectors. On the one hand, as some of African economies advance, with emphasis on the manufacture, assembly and maintenance of computing hardware and in industrial scale software development and software support, production of ICT goods will begin to share some of the characteristics of the secondary sector, in particular, aspects of production control, reliance on high-skilled labour, etc. On the other hand, in the economies that rely primarily on ICT applications for efficient running of industries, administration and services, ICT belongs to the tertiary sector, with obvious restriction of most applications being specific to each country and hence the non-transferability of related technologies between countries with differing practices. Regardless of these specificities, that is, whether an African country chooses to place emphasis on ICT applications or production of ICT goods, discussed in Section 1, there is a wealth of experience in technology transfer to be drawn from traditional economic sectors of the developing countries; see, for example, [7].

3.3. *Technology Transfer*

In relation to the two basic ways of advancing technology, namely, innovation and adoption [25], technology transfer as understood here is to be associated with the latter, that is, adoption of technologies developed elsewhere. Technology transfer has a significant impact, directly or indirectly, on the constituent capabilities of technological capability, introduced in Section 3.1 (see also Figure 2). Its predominant and immediate contribution would be to process and management capability (Figure 3) but it could also contribute to other capabilities. Figure 3 also shows (through arrows) the role of lower level capabilities (e.g. financial capability) in supporting the higher level capabilities (e.g. human resources capability). As is mentioned in the previous section, the technology transfer in ICT shares some commonalities with that in other traditional industries [34]. The account below places some of these in ICT and, where applicable, African contexts.

- Availability of human resource skills, availability of appropriate technological and institutional infrastructures, etc.
The importance of the above for capability development is already mentioned in Section 3.1. Other factors that could have an equally important bearing on the successful technology transfer, particularly in the African context, are: the overall state of the economy, government policies particularly with respect to investment, the availability of appropriate technological infrastructures in the public and private sectors, the demand for, and the interests of the local economy in, the technology concerned, and the social attitude or receptiveness for the technology. These conditions are unlikely to be met in most African countries because of their predominantly agrarian economic base, where poverty and low standard of living are major concerns and, as a result, matters such as the development of the necessary skilled labour and managerial expertise drop to a lower priority.
- The distinction between full and partial technology transfer
Depending on the form of the transfer being sought, the technology transfer can take place either partially or fully, with the obvious ensuing drawbacks and benefits. In ICT, partial technology transfer takes place with the adoption of foreign ICT applications in pursuit of efficiencies and may also be identified with outsourced technological processes. As with other technologies, partial technology transfer in ICT also results in increased dependence of the recipient on the

supplier of the technology. This is inevitable in the case of ICT applications but such dependence is not critical as in the case of other technologies acquired for economic development where least dependence on technology suppliers is often sought, or regarded as desirable.

- The need for involvement indigenous people in the production process for full technology transfer

In situations where the indigenous people are not conversant with the technology, as is the case with most African countries, it is necessary to acquire and assimilate the technology completely, including the required knowledge. This applies only to the production of ICT goods and, similar to other technologies, concerns the knowledge and know-how applicable right through the life cycle of the product concerned, from the design, manufacture or production, marketing, maintenance, etc.

- Implications of technology transferred being an expression of social values of the supplier nation
Being itself an artefact of human creation, any technology is also an expression of social values of the supplier nation. Therefore, a technology cannot usually be simply transplanted from one place to another. It needs to be adapted to suit the local conditions of the recipient nation, taking proper account of its cultural and social values, and any technological norms. In relation to ICT, this applies, for example, to user interfaces, linguistic aspects of ICT applications, content of educational software, various aspects of entertainment applications and the design of ICT devices such as mobile telephones. Manufacturers of such applications and devices are already paying attention to these aspects, though this is driven from commercial considerations directed at capturing the emerging African markets rather than any other considerations. African countries, however, need to approach this from a broader perspective, for example, to ensure the widest possible accessibility of the technology to the local users and, to ensure safe and beneficial use of such applications and devices by them, etc.
- Involvement of the transfer of both tangible and intangible asset in technology transfer
The technology transfer generally involves the transfer of both tangible and intangible assets, the former including machinery, capital goods, etc., while the latter the designs, plans, patents and other intellectual properties. In ICT, the latter is particularly important and the extent of the actual transfer would depend on factors such as the licence limitations (i.e. capabilities sought by the recipient in the technology being transferred), IPR issues, marketing agreements, and so on.
- The opportunity cost of not undertaking the technology transfer
Issues such as whether to adopt full or partial technology transfer necessarily involve economic and political decisions. The economic considerations may in turn involve an analysis of the opportunity cost of not undertaking the technology transfer concerned in the light of other alternatives, such as the possible expansion of existing technologies and the potential transfer of any alternative technologies. Because of the competing socio-economic priorities, these are important issues that need to be addressed by African countries seeking to advance their ICT capability.

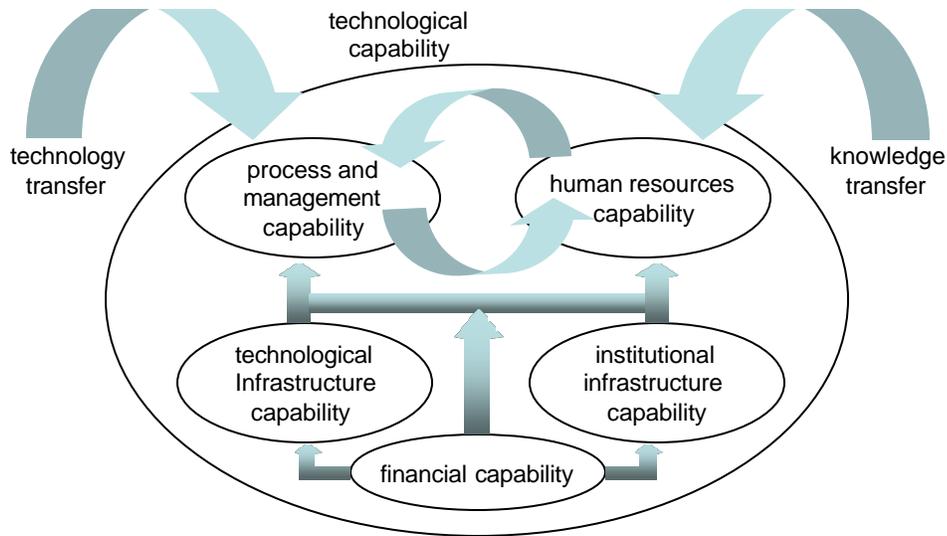


Figure 3. Capability building through technology and knowledge transfers

3.4. Managing the Technology Transfer

According to [34], the conventional forms of technology transfer in traditional technologies are:

1. R&D alliances (licensing agreements, technology and personnel exchange, joint development, research partnerships).
2. Manufacturing alliances (original equipment manufacture, second sourcing, and fabrication, assembly and testing agreements)
3. Marketing and service alliances (procurement agreements, sales and servicing agencies)
4. General purpose tie-ups (standards coordination and joint ventures)

The forms of technology transfer in ICT are not significantly different from the above [15]. However, in ICT, out-sourcing is perhaps currently a more predominant form of technology cooperation between firms in developed and developing countries such as India and China [15], though this could change over time as developing countries acquire greater capabilities in engineering and production of ICT products. Technology transfer related to ICT applications is likely to be restricted to marketing and service alliances. It is this form that tends to dominate ICT technology transfer in the African context in the foreseeable future. All four above forms are applicable to production of ICT goods. Though only the leading ICT countries in the developing world such as India and China are benefiting currently from these forms of technology transfer, those African countries already having some capability, or aspiring to gain a foothold, in the production of ICT goods need to promote them for widening the modes of ICT technology transfer.

Negotiation processes involved in ICT technology transfer are also similar to the practices in other technologies. Needless to say that the type of alliance to be adopted in a particular situation would depend on the needs and strengths of negotiating parties, and the price of the technology on market forces and the negotiating capabilities of the parties. These are unlikely to be favourable to most African countries and, therefore, there is a strong case for government involvement, for example, through incentives and underwriting; see Section 3.5 below. In the negotiation phases, the countries need to be aware of various additional indirect costs resulting from restrictions imposed by the parent company. These may include territorial market constraints, linkage of technology transfer to purchase

of goods and services, restriction on the recipient for entering into competing and complementary technologies, R&D restrictions, restrictions on adaptation and innovation, etc. [34]. They may have further effects, for example, on export capacity, higher import costs, expansion restrictions, consequences on balance of payments and the economic development at the national level.

3.5. National Policies

Since the African firms are unlikely to be able to negotiate technology transfers in ICT from a position of strength, the national governments in the African continent have an important role play. In addition to providing a visionary leadership, there are pragmatic reasons for governments taking a proactive role in promoting ICT technology transfer and making it happens; see [30]; [35]. As is mentioned earlier, it is costly for the less developed countries such as those in Africa to keep abreast in technological developments in ICT in the developed countries. Given its scarcity of resources, it is also important to prevent the reinvention of existing technologies. On the contrary, with increasing interdependence of nations, it makes much more sense for the less developed African countries to strive to achieve technology transfer through international co-operation in a mutually beneficial form.

Successful ICT technology transfers are likely to be undertaken in conjunction with the national industrial policies and taking into account factors such as indigenous capacity, consolidation of existing infrastructures, labour intensive measures, and country's R&D infrastructure [34]. As alluded to in Section 2, such a national industrial policy would identify the most promising areas for the technology transfer, as countries such as Singapore, Korea and Japan have done in their times of industrialisation. It would strike a right balance between the government role and the role of the private sector. It would also make the local economy attractive to foreign investment through proper infrastructures, right government policies, liberalisation of the economy, by promoting R&D investment at macro and micro levels and demonstrating, as China [30], Malaysia and Singapore managed, country's capacity to absorb technology transfer by investing in education and training in science and engineering. In addition, the governments may choose to play a particular role in specific cases of technology transfer.

3.6. Sustainable Development and ICT

ICT has both a role and an impact on sustainable development, depending on one's perspective, because sustainable development is a multi-dimensional concept with environmental, social and economic considerations. From the environmental perspective, the Report of the World Commission on Environment and Development (Brundtland Report) defines 'sustainable development' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [33] (Chapter 1 §27) and identifies the role of ICT in sustainability as the ability to 'help improve the productivity, energy and resource efficiency, and organisational structure of industry'. Experience of the industrialised world has shown that it is possible to make industries more resource-efficient and, thus, more profitable, while safeguarding the environment. ICT plays an important role in this respect, for example, in monitoring, gathering, forecasting and publication of environmental data and in establishing legal compliance with environmental laws and regulations [12]. In addition, decentralised distributed small-scale manufacturing supported by ICT provides an environmentally friendly, viable economic model for some of the less developed developing countries [33], which is a particularly attractive proposition for African developing countries. The African continent being one of the foremost and threatened ecosystems in the world, African ICT developers will therefore have an important role to play in its conservation through different means.

The above is a stance focussing primarily on the impact of the society on the environment, treating the ICT as a tool helping to take care of a sustainable development. However, there is another important aspect, that is, the impact of ICT on the society and, in particular, on the social fabric, that is, the sustainable development of ICT itself. A hint of this in the general industrial context may be found in the Brundtland Report [33], which states that “widespread poverty is no longer inevitable. Poverty is not only an evil in itself, but sustainable development requires meeting the basic need of all and extending to all the opportunity to fulfil their aspirations for a better life.” The significance of this in the context of new technology is highlighted in a persuasive argument [19] showing that because of its heavy bias towards skilled and educated labour the technological advancements of the new technology would tend to increase inequalities in both developed and developing countries. The reference to ‘sustainability’ and ‘poverty’ in [33] and to the widening ‘inequalities’ induced by the new technology in [19] has a strong resonance in relation to ICT. Such widening inequalities are evident between the poor and the rich in some of the newly industrialized economies forging ahead with ICT-driven industries. This is obviously an issue to be borne in mind in ICT development in Africa. In this respect, it is important to ensure that the development of ICT is itself sustainable in the sense that the benefits are spread out right across the African society equitably, that such development is not at the expense of poorer sections of the population, and that it should not replace or eliminate the traditional economic activities that affect the livelihood of the poor without proper alternatives in place.

4. Mechanisms of Technology and Knowledge Transfer

As is with other technologies, the mechanisms of ICT technology transfer vary, from those achieved through collaborative efforts to those achieved through independent effort. Generally, mechanisms achieved through collaboration include fully owned subsidiaries or joint ventures, purchasing of licences by payments of fees or through royalties, and technology transfer by foreign direct investors [34]. The latter may take the form of recruitment and training of local workers with the necessary technical and managerial skills to replace expatriates or specifically with the aim of enabling them to start new domestic enterprises and to modernise existing enterprises.

4.1. Foreign Direct Investment (FDI) and Knowledge Transfer

As evident from numerous studies, including the OECD Working Papers [3], [5], [13], [16], [21], [24] and [27], and [11], there is widespread agreement about the important role of foreign direct investment (FDI) by multi-national enterprises (MNE) and international organisations in knowledge transfer and, hence, in human capital formation, in particular, through direct provision of education, training in new skills, bringing in new information and other technologies to the host country. In addition to increased competition and subsequent efficiency gains in local firms, the presence of MNEs has a direct impact on diffusion of skilled labour and management skills trained by MNCs to the local industry, greater inspiration for adopting new technologies, and the technology transfer to local suppliers via outsourcing.

An aspect that is of primary interest here is the extent of validity of the above observations for ICT and the role of human capital in attracting FDI. Though there are analytical and other works such as [11] and [13] in this respect, attempting to establish a causal relationship between ICT and FDI, there appears to be no clear-cut evidence on any causal relationship between human capital development and FDI. With reference to knowledge transfer in general, Miyamoto [16] draws certain observations from the findings due to two groups of research studies. Based on separate data sets belonging to different historical periods, namely, a) 1960s and 1980s; and b) 1980s and to mid 1990s, Miyamoto examines the significance of human capital in attracting FDI depending on the skill levels required by the incoming FDIs. Specifically, the human capital associated with labour intensive low-end

manufacturing during the period (a) above appears to play no noticeable role in attracting FDI, while the human capital associated with high value-added manufacturing during the period (b) above is having a positive effect in inward FDI. This observation appears to make some sense in the light of the general shift of FDI in favour of high-tech manufacturing during the recent years. Therefore, human capital appears to be “an important determinant for inward FDI among the efficiency-seeking MNEs while not an important determinant in resource-seeking MNEs” [16].

The above observation has important implications for ICT in African developing countries. Firstly, it is consistent with the current nature of inward FDI flowing to Africa, namely, its exclusive concern with the exploitation of Africa’s rich natural resources. For example, the share of primary goods remains high and constant in Africa, which is seen as a sign of natural resources continuing to remain the attraction for MNEs in Africa [16]. This is in sharp contrast to what is happening elsewhere². At the same time, there is a marked cross-regional disparity in FDI, for example, five largest host developing countries attracting 62% FDI and African countries lagging behind considerably in attracting FDI compared to the developing countries in other continents [16]. This is an important issue that needs to be addressed with a view to identifying what positive steps can be undertaken by the less successful developing African countries in order to rectify the imbalance. In the meantime, however, it seems sensible for African countries rich in natural resources and wishing to advance ICT capability to maintain this resource-seeking interest of MNEs to national economic advantage and treat it as a stepping-stone to extend MNE activities gradually to high-tech efficiency-seeking industries, for example, through fiscal transfers and government incentives [35]. For example, according to the experience of South East Asian countries, government incentives tend to encourage large firms involved in high-tech manufacturing for export to provide training [24].

In order to attain this, however, significant efforts should be directed towards improving the human capital through other means, to begin with, through formal educational means. This can be strengthened by the creation of institutions for industrial upgrading of skills, though, as evident from the experience of Southeast Asian countries, absence of such institutions beforehand is not necessarily a handicap for attracting FDI [24]. Interim benefits of enhanced human capital even prior to attracting efficiency-seeking MNEs are many; they will help to create right social and political conditions for attracting FDI through better governance, reduction of corruption, civil liberties, awareness of civil responsibilities, etc., all contributing to instilling the sense of ‘common purpose’, mentioned in Section 3.1, right across the society. These conditions appear to differ considerably between African countries and developed countries such as Singapore and Germany; see [1] for specific country case studies.

Findings in [16] suggest that the secondary school education is the minimum level for attracting relatively high valued-added, efficiency seeking FDI. Since it has to be undertaken at national level, even achieving this to an adequate level requires considerable effort. In the interim, however, there is considerable scope for Africa to change its image by raising its educational profile at the tertiary level selectively in ICT-related courses. This would require supporting leading computing and IT departments at universities and other tertiary educational institutions in each country significantly with targeted funds and in collaboration with specialist educationalists.

4.2. Other Means

² The trend in elsewhere may be characterised by a marked growth of the share of the services sector in developing countries (to more than twice the primary and manufacturing sectors taken together) with an equal decline in the primary goods sector, manufacturing sector still dominating other sectors in FDI (reaching as high as 51.2% in China in 1993), and a shift towards technologically advanced FDI [16].

Reproduction of a capability through reverse engineering is an independent mechanism of technology transfer [34]. Reverse engineering being an active research topic in computing, there are tools and methodologies for reverse engineering, making it a particularly attractive approach in ICT technology transfer. Generally, it involves breaking up a product, or analysing a piece of software, and rebuilding it with one's own knowledge and resources. In the case of ICT products, the reverse engineering of programs can be prevented by restricting the product distribution to binary code, but the design of systems and devices may be worked out, to an extent, through observation of their behaviour (e.g. in tests). However, capability building through reverse engineering does not come free, as it carries the risk of disputes and controversies because of the unilateral or non-collaborative nature of such actions.

A less formal form of technology transfer, which is becoming quite common in ICT development in Asia, is through international community networks of a given nation. It is predominant among the overseas Chinese and Indian communities, who tend to maintain their traditional relationships with the home communities through transfer of capital, propagation of technical know-how and exchange of entrepreneurial skills. Similarly, in the African context, the African diaspora³ in the Western world could be a significant source of ICT specialists, entrepreneurs and well-wishers that could be tapped for ICT development in Africa. The technology transfer also takes place through mobility of trained personnel. Migration of skilled workers and reverse engineering have played this role before in the early stages of industrial revolution and innovation efforts undertaken in R&D laboratories later on [9].

4.3. Institutional Structures Required for Supporting Technology Transfer

Institutional infrastructure supports and facilitates technology transfer, and may also provide training activities outside formal education (see below). In addition, there are nowadays institutions other than universities and other academic institutions which are engaged in 'knowledge production' [15]. Generally, the institutional infrastructure includes the following:

a) R&D institutions

In many developing countries the majority of the scientific and engineering personnel are employed in research institutions in the government sector but in areas such as agriculture, health and other public services. Generally, industrial institutions are rare or non-existent. As these countries look towards technology transfer, there is a strong case for embedding any existing, or newly created, industrial R&D institutions, especially in ICT, within the industries themselves, but taking care to institute special measures (e.g. incentives) to ensure product innovation, technology acquisition, knowledge dissemination, training, etc.

b) Scientific and technical services

Such services include regulatory structures, technical libraries, bodies for introducing and enforcing standards, professional societies authorised with accreditation rights and for maintaining professional standards, a body for protecting IPR and patents and advisory services.

Because of their significant operational cost, in the case of most African countries it may be appropriate to consider, from a sustainability point of view, the formation of such institutions and services at a regional level.

³ The indigenous peoples of Africa and their descendants spread beyond the African continent

5. Measuring Technological Capability

In attempting to measure the capacity of a nation to take advantage of its human and other resources for economic development through advancement of its technological capability, it would have been ideal, in the light of our discussion in Section 3.1, if we were in a position to measure the level in each of the constituent capabilities shown in Figure 2. This is beyond the scope of this work and, therefore, this section covers the indicators used for measuring the overall technology capability at an aggregate level in Section 5.1 and those for measuring human potential in more detail in Section 5.2. This treatment inevitably results in some overlap of the two categories of indicators.

5.1. *Technological Capability Indicators*

The appropriateness of technological capability indicators used in relation to developing countries depends not only what questions that need to be answered but also on the relative maturity of the economies of these countries. The latter is due to the relatively poor quality of available historical data in these countries, in particular with respect to data availability and reliability, coverage and significance [2], [32], compared to those of the developed countries. Although organisations such as UNDP take various measures to overcome, or compensate for, these inadequacies, an appreciation of the nature of the statistical data is vital, especially when attempting to draw comparisons of cross-country potential

In addition to internationally agreed statistical measures, both within UN organisations and other organisations such as the World Bank, there are other approaches such as ArCo [2] attempting to draw more realistic cross-country comparisons across a larger sample of countries by taking into different capability dimensions, focusing on indicators with a more satisfactory coverage and by filling in any missing gaps through estimates based on expert opinions and comparisons with similar economies. UNDP's Human Development Index (HDI; see also Footnote 4) [32] is based on three basic dimensions: basic human development as captured by life expectancy, knowledge as captured by literacy rate, enrolment rates of students to primary, secondary and tertiary educational institutions, and the standard of life as captured by the GDP. UNDP recognises the limitation of some of these dimensions; for example, it calls for a new 'literacy profile' in [32] that takes into account a wider range of individuals' skills such as reading, writing and numeracy to replace the simple literacy rates currently used in its Human Development Report. On the other hand, ArCo [2] is specialised on technology and uses eight attributes under three capability dimensions: technology creation (captured by patents and scientific articles), technology diffusion (as captured by the Internet penetration, telephone usage and electricity consumption) and human skills development (as captured by literacy rate, years of schooling and enrolment to tertiary science and technology institutions).

A directly relevant work to this study is [17], which is a comparative study of trends in ICT development over the period 1995-2001 of 14 countries belonging to three groups: developed countries (US, Ireland, Finland, Switzerland and Japan), newly industrialised countries (South Korea and Singapore), and developing countries (Malaysia, Thailand, Indonesia, the Philippines, Mexico, Chile and Brazil), with the aim of drawing lessons for developing countries. Its data sources are: IMD World Competitiveness Report (1995–2003), World Intellectual Property Organization (WIPO) (1995-2001), Digital Planet 2002: The Global Information Economy and the United Nations Statistics Database. It uses fourteen variables classified into four categories: ICT infrastructure (Internet penetration, per capita IT hardware expenditure, per capita software expenditure, per capita telecommunication investment, number of PCs used at home per 1 million people), human capital (per capita expenditure on public education, competitive educational index: appropriateness of educational system for a competitive economy based on a survey), innovation (R&D personnel per 1000 people, per capita R&D expenditure, patent productivity per 1000 R&D personnel), and

productivity (labour, industry, service, overall). Compared to other systems of indicators, the use of a competitive educational index to account for the quality of education is an important contribution of this work. This is based on a survey of responses by 2500 senior executives; unfortunately [17] contains no details about the nature of this survey.

The overall findings of the above work [17] are that the developing country group, as expected, lags behind the other two groups of countries in almost all categories, though the Latin American countries and Malaysia seem to be ahead the rest in the same group in ICT infrastructure, human capital and innovation. Though there are important lessons to be drawn, the developing country group considered is not representative for most of the African countries to be considered in our work.

It is also instructive to compare the above indicators with the metrics recommended by the Science and Engineering Indicators [18] of the National Science Foundation (NSF S&T indicators) for assessing IT capability in the US; these are: IT diffusion indicators (e.g. IT investments in industry, IT hardware and the Internet access in the school classroom), economic impact measures (these are recognised to be industry sector-specific, the ones specific to banking industry being volume of transaction processing, transaction costs relative to transactions processed by humans and processing times of transactions) and the quality of life indicators (e.g. protection from health hazards and breaches of security, entertainment, etc.).

Although some of the above NSF S&T indicators are somewhat ambitious for many of the developing countries in the African continent, they nevertheless serve a useful purpose, namely, that they highlight the need for choosing the indicators that are right for the economic and social context under consideration and that they provide a longer-term perspective for the strategic planners engaged in capability development in developing countries. For example, in the context of African countries, in order to meaningfully pose, and answer, questions pertinent to them and, hence, guide their capability development in ICT, it is necessary to consider ICT-specific indicators suitable for the African context. The other side of the coin is that some caution is to be exercised in the extrapolation of some of the comparisons and, hence, observations made later in this work, based on UNDP data under rather general criteria, to assessing both the potential and the challenges faced by African economies in developing their ICT capability. Therefore, it is vital that we carefully examine the indicators to be used in assessing the role and the impact of ICT in Africa.

A specific case in point is that, because of the cost of immediate expansion of tertiary education in ICT on a wide scale, it would be more cost-effective for the African countries to target any available resources at the most promising areas of ICT from their economic perspective and to deploy such resources as efficiently and effectively as possible. This could be facilitated by having a combined measure that incorporates both quantitative and qualitative aspects (similar to the competitive educational index in [17]) of such education, that is, by considering a weighted measure of student enrolment rates, or even a more refined metric such as the student graduation rate that automatically disregards the drop-out of students between enrolment and completion, and such metrics as course portfolios vital to country's economic objectives, course accreditation by professional bodies, etc. The weights in the combined measure can be chosen in such a way that an appropriate balance can be maintained between, on the one hand, the training of high-quality graduates with the potential for driving innovations and entrepreneurship for setting up of new businesses and, on the other, the training of graduates required for less demanding roles in the economy, for example, technical support for industrial and commercial enterprises, manufacturing and maintenance of IT products and services, etc.

In devising indicators for measuring the economic impact of ICT, another important point that has to be borne in mind is that made in [18], [22] and elsewhere with regard to the 'productivity paradox' –

the difficulty in detecting a clear statistical correlation between IT investments and the productivity in the private sector – and its possible dependence on our natural expectation of positive results from the deployment of IT in industry. There are also works such as [17] (based on a comparative study of historical trends) that affirm productivity rises in countries investing heavily in infrastructure, education and innovation. The immediate question is, however, whether the productivity gains are measurable in a meaningful manner, that is, in a manner that they are attributable solely to ICT, and, if so, how to go about measuring them. According to [18], some of the important issues are: 1) the need for a standard definition of IT costs: do they comprise just capital investments or include, in addition, the usually high operational labour costs; 2) treatment of IT costs in accounting, whether as an annual ‘flow’ of expense or as part of cumulative ‘stocks’ (due to rapid obsolescence of IT equipment and ever falling prices of computer hardware); 3) the difficulty in measuring the contribution of activities such as accounting with intangible outputs; and 4) the contribution of IT to both efficiencies and higher qualities at the output front and cost savings at the input front as well as through the production process [22]. Added to this is the apparently long time lag, possibly decades, between the time of introduction of a new technology and the time when the society tends to accrue its real benefits. These factors make it harder to come up with indicators that could realistically measure the economic benefits that can be gained in developing African economies through investment in ICT, especially in view of the fact that such investments are likely to be at a much lower scale and made at a much lower economic base in comparison to the early stages of deployment of IT in industry and commerce in the developed countries.

5.2. Human Capital Indicators

The skills base of the workforce is the most basic factor determining the success, or the failure, of any industry, including ICT, and hence its impact on the economy. Its creation through education is also one of the costliest items in any national budget, in addition to being one of the most difficult tasks facing any country. Therefore, from budgetary, as well as from performance, points of view, it is important to be able to measure the educational attainment of the population as a whole. Human capital indicators are such measures. Since they reflect the educational attainment at an aggregate national level, they are necessarily rather crude measures and ignore important factors such as the actual skills and competences accomplished at the point of completion of studies, personal characteristics such as motivation and commitment of individuals, so on. Nevertheless, they are an important means of evaluation of performance of educational efforts leading to economic development.

The OECD report on Human Capital Investment [20] defines human capital as “the knowledge, skills, competences and other attributes embodied in individuals that are relevant to economic activity” and regards it as “an intangible asset with the capacity to enhance or support productivity, innovation, and employability”. Human capital is created through a variety of complementary means [20]:

- Formal education (provided by educational institutions at different levels: kindergarten, primary education, secondary education, vocational training, tertiary education, adult education, distance learning, etc.)
- Non-formal education (provided by enterprises and public organizations through training and R&D activities)
- Learning in informal environments (taking place within families, in communities, through media and information networks, societal learning, learning by doing, learning by observing others)

Among the widely used human capital indicators for measuring the attainment levels of the current working population are [20]:

- a) Percentage of the relevant section of the working adult population (adults in the age group of 25-64) to have successfully completed a given level of education (e.g. secondary, upper-secondary, tertiary, etc.; advantage: an internationally agreed measure by the International Standard Classification of Education (ISCED); drawbacks: no reference to the actual skills and competences acquired and their inconsistency (variability) in the definition of attainment levels across countries, inconsistencies in classification of educational programmes under different levels (e.g. vocational programmes under upper-secondary level)
- b) Years spent on education at, or up to, a given level (advantage: a single measure to deal with; drawbacks: assumes human capital grows proportionately with each year, irrespective of the level of education, an indicator less variable from country to country and hence its inability to sharply discriminate between attainment levels of different countries; programmes of some countries relatively longer periods to complete)

Note that (a) consists of several measures, one for each level of education being considered, and, hence, gives a better profile of the educational attainment of a given country, whereas (b), being a single number, gives a more abstract measure and is not necessarily in conformity with (a) in substance. This is in addition to the various advantages and drawbacks mentioned under each above.

The other factors that may need to be taken into account in assessing the educational attainment in greater detail are [20]:

- The changes in educational attainment over time.
This is relevant to situations undergoing rapid and significant expansion of the educational system, due to increased demand or policy initiatives, perhaps as a response to rapid growth of the economy. Basically, it is a comparison of attainment of a given educational level of two (or more) cohorts of different age groups taken from a fixed number of years apart. Since any expansion of education in African countries is unlikely to meet the above criteria, this indicator is not relevant to the current African context.
- Educational attainment of different groups
These groups may be defined by gender, generational difference and intergenerational mobility (likelihood of better educated offspring coming from less educated parents). Here, educational attainment by gender could be an important indicator in the current African context.

Though the indicators listed above are useful to an extent, they suffer from some well-known drawbacks, such as

- Non-uniformity of knowledge and skills as reflected by the education attainment levels from country to country
- Omission of knowledge and skills acquired through means outside the formal educational system in education attainment levels

In order to overcome such deficiencies, an alternative measure is suggested in [20] based on a set of skills (e.g. prose literacy, document literacy, etc.) tested on actual tasks performed in a simulated work environment and detailed interviews of a sample of individuals.

6. Opportunities and Challenges for Africa

6.1. Current State of Human Capital in Africa

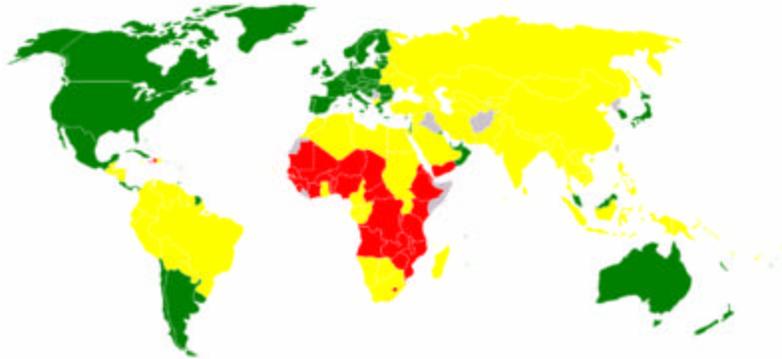


Figure 4. World Map by Human Development Index (Source: Wikipedia):
■ high (0.800 - 1), ■ medium (0.500 - 0.799), ■ low (0.300 - 0.499)

6.1.1. About the Data and Figures

Using the data given in the UNDP Development Report [32] and an Analytical Survey of the UNESCO Institute for Information Technologies in Education [4], this section gives an overview of the current state of human capital in African countries. Its purpose is to highlight the positions occupied by different African countries in relation to one another and, more importantly, to developing countries from Asia and Latin America, which have shown significant or some achievements in ICT capability building. The UNDP data [32] relevant to Africa come under the two lower classifications of human development, medium and low, out of the three classifications by Human Development Index (HDI; mentioned also in Section 5.1): high, medium and low⁴; see Figure 4. Therefore, some of the comparisons are given separately for these two categories. Note that a) our observations are based on visual comparisons of graphical presentations and not on a statistical analysis of the data, and b) countries with missing data under a given attribute are not commented upon in our commentary below.

Here are a few notes on how to read the figures. **Error! Reference source not found.** shows, for example, the public expenditure on education as a whole as a percentage of GDP, and on secondary and tertiary education as a percentage of the total education budget (i.e. for all levels of education) for the year 1990 and for one of the years in 2000-2002 (shown in figures simply as 2000-02) for countries with medium human development (medium HD). **Error! Reference source not found.** shows the same for countries with low human development (low HD). Note that in the case of certain countries, some of the above data may be missing and hence are not shown in the figures. Superimposed on the same figures (by labeled horizontal lines) are the levels of corresponding to expenditures by reference countries, India and Mexico, in these two figures. The choice of reference countries is quite arbitrary, except that in most cases (except, for example, Peru) they are all known for higher degree of achievements in ICT compared to African countries.

⁴ HDI is a comparative measure of life expectancy, literacy, education, and standard of living for countries worldwide. It classifies countries into three categories: those of high human development (with an HDI of 0.800 or above), medium human development (0.500–0.799) and low human development (less than 0.500).

6.1.2. African Expenditure on Education

Reference Country	Expenditure on education (% of GDP or edu. Budget; 2000-02)		
	All (% GDP)	Secondary (% of all levels)	Tertiary (% of all levels)
India	4.1	40.1	20.3
Mexico	5.3	28.7	19.6

It may be seen from **Error! Reference source not found.** that among the medium HD African countries the total expenditure (as a percentage of GDP) is generally comparable with our reference countries, India and Mexico, with the exception of Equatorial Guinea and Uganda (based on data only for 1999), though there is marked drop in expenditure in the case of Botswana in 2000-02 period. In the low HD category shown in **Error! Reference source not found.**, Swaziland, Lesotho, Kenya, Eritrea, the Ivory Coast, Malawi, Burundi compare well, while others fall below to varying degrees. In secondary education, all medium HD countries lie within, or comfortably close to, the band 25-40% where India and Mexico lie, while Equatorial Guinea stands at 18.1%. Among the low HD countries Kenya, Gambia and Malawi lie close to 20%, Rwanda at 16.7% and Mozambique at 15.7% and others in the band 25-40%. In tertiary education, all countries except South Africa, Togo, Swaziland, Lesotho, Rwanda, the Ivory Coast, Zambia and Burundi are noticeably below the Indian and Mexican level of roughly 20%. These data clearly indicate that the expenditure on education by most African countries is low in comparison to the two reference developing countries, both being known for ICT.

6.1.3. African Literacy

Reference Country	Literacy rates(%; 2003)	
	Adult	Youth
India	61	76.4
Brazil	88.4	96.6

As is shown in **Error! Reference source not found.**, literacy rates for both adults and youth among the medium HD African countries compare well compared to our reference countries, India and Brazil this time, with the exception of Comoros. In the low HD category shown in **Error! Reference source not found.**, the picture changes quite significantly, Mauritania, Gambia, Senegal, Benin, the Ivory Coast, Mozambique (adults only), Ethiopia, Central African Republic, Guinea-Bissau, Chad, Mali, Burkina Faso, Sierra Leone and Niger all lying below our reference country levels, 61-88.4% adult literacy rates for India-Brazil (in that order) and 76.4-96.6% youth literacy rates for India-Brazil. Thus, in respect of literacy, a large number of low HD countries in Africa are a concern.

6.1.4. Primary, Secondary and Tertiary Student Enrolment in Africa

The data for our reference countries are:

Reference Country	Enrolment rates %		
	Primary	Secondary	Tertiary: Maths, Sci. & Eng
Indonesia	93	70	40
Costa Rica	85	81	31

a) Primary Education

As is shown in **Error! Reference source not found.**, among the medium HD African countries, in primary education it is only Comoros, Ghana and Congo that fall below the rest in a band 54-60%;

others being comparable to Indonesia and Costa Rica. Among the low HD countries shown in **Error! Reference source not found.**, however, only Madagascar, Lesotho, Gambia, Nigeria and Tanzania are close enough to Indonesia and Costa Rica; others all lie in a band 36-75%.

b) Secondary Education

In secondary education, all countries except Mauritius and South Africa, followed immediately below by Cape Verde and Botswana are way below the reference country performance; see **Error! Reference source not found.** and **Error! Reference source not found.**

c) Tertiary Education (Maths, Science and Engineering)

In tertiary education in mathematics, science and engineering, only Mauritius, Ghana, Kenya, Benin, Tanzania, Malawi and Zambia compare well with the reference country performance; see **Error! Reference source not found.** and **Error! Reference source not found.**. All others fall near or below 20%.

6.1.5. Communication Technologies

Reference Country	Users per 1000 people in 2003		
	Telephone	Mobile	Internet
Mexico	160	295	120
Malaysia	182	442	344
Thailand	105	394	111
Peru	67	106	104

In the use of communication technologies, the pattern of telephone, mobile phone and Internet usage tends to vary widely from country to country; only in the case of countries such as Mauritius, Cape Verde, Namibia and a few others a reasonable balanced picture exists. In the case of other countries, mobile phone usage tends to dominate the other two, perhaps as a sign of the relatively poor state of the latter. For example, only 3% of Africa is connected by landlines.

Limiting ourselves in the discussion here to medium HD countries (**Error! Reference source not found.**), except Mauritius, Cape Verde, South Africa (mobile phones only), Gabon (mobile phones only) and Botswana (mobile phones only) other countries compare unfavourably to our reference countries (excluding Peru).

6.1.6. African Contribution to Innovation

a) Royalties and Licence Fees

As is seen in **Error! Reference source not found.**, the sample of data is too small for any generalisations. In addition, it is unclear how much of these fees are royalties for literary works and how much are for technical works.

b) R&D Expenditure

As is seen in **Error! Reference source not found.**, the sample of data is again too small for any generalisations but the available data compare favourably against the reference countries: Chile at 0.5% of GDP and Malaysia at 0.7% of GDP. It is unclear how much of this expenditure is spent on technological R&D work.

c) R&D Workers

As is seen in **Error! Reference source not found.**, the available data on Cape Verde, South Africa and Guinea compare favourably against the reference countries: Mexico with 259 workers per million people and Thailand with 289 workers per million people. Other countries with any data lie below 50 workers per million people. The ratio of workers on technology related R&D work is unclear in the data.

6.1.7. African Emphasis on Science and Engineering

Based on the data given in the Analytical Survey of the UNESCO Institute for Information Technologies in Education [4], next four figures, **Error! Reference source not found.-Error! Reference source not found.**, show percentages of students in tertiary education in 21 African countries and 6 non-African countries (India, Korea, Japan, Vietnam, Costa Rica and Mexico; this group is referred to as Asian and Latin American sample, or ALAS) studying the subject areas, given in the first column of the table below.

	Averages (% of all)		
	African	ALAS [†]	Developed Countries
Humanities, education, social sciences, business and law (Error! Reference source not found.)	69.8	54.7	57.8
Science, engineering, manufacture and construction (Error! Reference source not found.)	14.4	26.6	26.3
Science (Error! Reference source not found.)	8.7	10.4	12.7
Engineering, manufacture and construction (Error! Reference source not found.)	6.4	17.9	10.3

† Asian and Latin American sample

The above summary clearly shows that, compared to both developed countries and the sample of Asian and Latin American countries featuring in the figures, African tertiary education is geared toward producing more graduates in non-technical subjects (humanities, education, social sciences, business and law) than in technical subjects. The implication of this is very clear, that is, most African countries are not producing enough graduates as required by modern technological economies even for using ICT for efficiency purposes. Furthermore, since science and technology play an important role in innovation [15], this is a serious barrier for some African countries to become knowledge-based economies. The figures also show how individual countries fare in relation to the same goal. Ghana, Kenya and Mauritius do well in relation to engineering, manufacture and construction, and a relatively large number of African countries also do well in science, even better than the averages of other two categories of countries. Yet, the overall picture is not favourable for technology-oriented economies.

6.1.8. Summary

The above discussion confirms nothing new but simply brings into focus the real state of African human capital. Investment in education, the student enrolment pattern across different educational levels and student numbers in technical education are not in line with those expected in (relatively) modern industrial economies of the developing world. Technological infrastructure, as expected, is inferior to other rapidly developing countries in Asia and Latin America. However, penetration of mobile phones and wireless networks [7] seems to suggest the viability of alternative ways creating an advanced telecommunication infrastructure in some African countries. Major efforts are required

to bring innovation, research and development into line with other competitors, especially in the areas of technical subjects. Note that since no relevant data are available, our discussion does not address the needs of ICT at all as seen from the capability building point of view.

6.2. Experience of Countries from Elsewhere

Given the above situation, it is instructive, and inspirational, to examine how a number of developing countries across Asia and Latin America, many with economic backgrounds similar or worse compared to some of the African countries a few decades ago, managed to pull themselves to the forefront of ICT revolution within a short historical period. African countries, as well as other developing countries across the world, could benefit immensely from the experiences of these countries. Here are just three such countries, which have taken different paths to become some of the leading countries in high-tech industries and ICT product development.

6.2.1. Singapore

Singapore's rise to the league of newly industrialised countries within a relatively short historical time span is not only relevant to our study but also, in terms of economic development, exemplary to other countries aspiring to achieve rapid industrialisation. Since its formation in 1965 after expulsion from Malaysia, recognising its natural handicaps such as the lack of natural resources and being a small island-state of approximately 700 square kilometres (including reclaimed land) and its demographic limitations by having a small poorly educated population consisting of farmers, fishermen and traders, Singapore embarked on a rapid programme of education, raising itself from a low scientific base to a nation with a highly skilled workforce.

To counter the small domestic market, Singapore followed an export-led path with policies designed to attract foreign investment, initially into labour intensive industries but gradually diversifying into more and more skill-intensive industries such as electronics and computing hardware, thus creating a virtuous cycle of knowledge and technology transfer and further foreign investments. For example, in 1980s Singapore concentrated its effort on labour-intensive assembly of consumer electronics and semiconductor components, in 1990s it switched its attention to technology-intensive manufacturing of advanced ICT products such as disk drives and it recently moved towards R&D activities, each time consolidating its achievements with frontier technologies [22] (Chapter 10). This has been complemented with diversification of the economy into other areas, notably into finance and other service sectors.

The above has been backed up strategic proactive investments by the government in a modern communication infrastructure, for example, the installation of a nation-wide broadband network in 1990s, as the technological pillar for supporting a modern knowledge-based economy. At the same time, the government has been taking a proactive role by encouraging foreign hardware and software vendors and companies to invest in Singapore, promoting indigenous IT firms and boosting the internal demand for ICT by extending the use of ICT by the public sector, a typical example being Singapore's civil service computerisation programme [22] (Chapter 10).

Though the above achievements were, arguably, at the expense of some aspects of liberty, absence of corruption, the reputation of disciplined workforce and the political stability have also been conducive to attracting foreign investment. Better social wellbeing, high standard of life and harmonious race relations have instilled a sense of 'common purpose' among her citizens and helped to channel their commitment and energy to productive ends. The pragmatism shown by maintaining the English language as the medium of instruction in technical education (especially, tertiary) has made her educated workforce outward looking, with immediate benefits such as easy access to the

technical advances made in the developed world through literature and training, as well as access to the employment opportunities available through foreign companies operating in Singapore. The net effect of all these factors, educational, technological, political and cultural, is that today Singapore hosts some 3000 multinational corporations, together accounting for more than two thirds of her manufacturing output and export, and exhibited a GDP growth rate exceeding 7% over the period 1975-99 – more than twice as that of the OECD countries.

6.2.2. *India*

Despite being dubbed as an emerging global economic superpower, India is a land of extremes, whether it is in material well-being, health, education and transport. The gaps between ‘haves’ and ‘have-nots’ are continually widening, though nowadays not so much because of “problems of a complete failure of the state – but of incomplete successes, mixes of failure and success, of achievements that create new challenges” [23]. The lessons for us are, however, not in India’s failures but in her successes.

One of India’s greatest fortunes has been her endowment with some rare individuals as her leaders at many levels of the society. The world acclaimed Indian Institutes of Technology (IITs), the pinnacle of India’s achievements in technical education, were conceived even before her independence in 1947. Recognising that “the future prosperity of India would depend not so much on capital as on technology” [36], Sir Ardeshir Dalal of the then Viceroy's Executive Council envisaged the formation of laboratories under the umbrella of the Council of Scientific and Industrial Research (CSIR), an institution at the helm of India’s drive for excellence in science and technology, and conceptualised institutes of the nature of IITs for training specialists locally to run them, instead of training them abroad. In addressing the first convocation of the first IIT at Kharagpur, Jawaharlal Nehru, India's first Prime Minister, proclaimed in 1956 “Here in the place of that Hijli Detention Camp stands the fine monument of India, representing India's urges, India's future in the making. This picture seems to me symbolical of the changes that are coming to India” [36]. This was the vision of a nation, known to the rest of the world then for its poverty rather than its science, at a time when nobody could count on an impending ‘globalisation’ that could help Indian enterprises and entrepreneurs to lift India out from the bottom of developing club to become an economic superpower. The most remarkable was the fact that this vision was turned into reality within one’s life time through dedication and hard work of many. The credit goes no less to India’s political leadership, in particular, the prime ministers starting from the visionary Jawaharlal Nehru, who showed their commitment to, and direct interest in, development through science and technology by occupying the Presidency of CSIR.

Graduates from India’s seven IITs today, spread over different parts of the country, and from other leading Indian institutions are now sought after in the USA and in Europe. Indian scientists have a worldwide reputation for their achievements. They have demonstrated to the world at large that Indian technology is a force to be reckon with, especially in software industry [28] with China providing a strong challenge [30]. With the economic reforms introduced in 1990s, leading to opening of certain sectors of her economy to private and foreign investment, India is now well placed to reap the well-deserved rewards for decades of investments in technical education. Reverse brain-drain of Indian nationals returning from the West, with years of extensive professional, managerial and entrepreneurial skills in the developing world, has not only given rise to an influx of capital into the country but is playing the role of a technology transfer through a form that no other developing country is likely to experience, namely, in the form of highly skilled experts and industry leaders themselves as knowledge carriers. The nature of technical education also gives an edge to India over other newly industrialised nations in the region. Maintenance of a good all-round education in science, use of the English language as a medium of instruction, exposure to Western thought and

literature including those in scientific disciplines without interruption in post-independence era, etc., have all left India well-placed to compete internationally, even in advanced Western countries, in all areas of high-tech goods and services, particularly in ICT.

6.2.3. Costa Rica (based largely on [6])

Better known until recently for its agricultural produce, e.g. coffee beans and bananas, Costa Rica has become, through careful planned diversification of the economy, another success story in Latin America, alongside countries such as Brazil and Mexico. Sound economic and social welfare policies, combined with a stable political climate, have transformed the country into one with a high standard of living. It now exports more Intel microchips than coffee or banana; the former taking 37% of the export share in 1999 compared to 10% and 5% of the latter, while the exports are continually rising, roughly at 20% per annum.

All this has been a culmination of technology capability building policies put in place on all fronts over a comparatively short period of around 15 years. To begin with, Costa Rica's human capital development programme included actions such as introduction of computing to school curriculum, introduction of innovative learning techniques with the help of non-profit Omar Dengo Foundation set up in 1987, and turning of the Costa Rican Technological Institute (ITCR) into a premier ICT school. Educational achievements of the population are impressive with an illiteracy rate below 3.5% and 18.5% of the active population having some form of tertiary education in 1999.

The above has been complemented by the creation of the university-supported National Center of High Technology (CENAT) in 1997 to promote innovation and scientific advancements. Commitment to professionalism in production processes has been demonstrated by actions such as the formation of a Program for the Improvement of the Software Sector. To underline the safeguards and respect for intellectual properties, the relevant international agreements have been signed.

Technological infrastructure consists of high-speed submarine cables connecting Costa Rica to the US and an efficient Internet infrastructure across the country. Telephone coverage is one of the best in Latin America with 1 telephone for every 5 people on average, compared to 1 for 20 people in the neighbouring Central American countries.

The government makes good use of fiscal policies to promote ICT and attract MNEs. Investment in ICT strategy was around 8.3 percent of GNP in 1999. The government has reallocated funds from defense to education. It has taken the initiative to use ICT to improve its own services. It has reduced taxes on computers and introduced incentives to attract foreign companies through free trade zones, going as far as introducing electronics and English language into high school curriculum specifically to attract an MNE (viz. Intel) [27]. As a result, the country now hosts 32 foreign electronics firm including software and hardware giants such as Microsoft, Lucent and Intel. FDI amounts to US\$530 million per annum currently, that is, roughly 5% of GNP.

6.2.4. Reflections

The experiences of the above three countries highlight certain factors that helped them to undertake significant steps towards establishing knowledge-based economies through investments in ICT capability in varying intensities over short to relatively modest periods of time. African countries could certainly benefit from these experiences, despite the three countries not being quite representative for the African context. Broadly speaking, all three countries highlight, amongst others, the importance of the following:

- Visionary political leadership
- The need for a liberal economy and an appropriate stable political framework
- Proactive role of governments
- Instilling a sense of ‘common purpose’ among citizens
- Having a strategy for raising the level of the human capital
- Timely setting up of required technological and other infrastructures
- Having a strategy for phased development of ICT and other high-tech industries
- Promotion of English language for technical education

7. Means of Human Capital Development

Among the predominant means of human capital development are formal and non-formal education and learning-by-doing in real ICT enterprises.

7.1. Human Capital Development through Formal Education

Basic and certain advanced skills and scientific knowledge acquired through formal education are an essential prerequisite for technology transfer to any developing country. In creating such a knowledge- and skill-base, it is inconceivable how this could be achieved in the medium- to long-run without raising the general level of education of the country’s population as a whole and without creating a strong science base incorporating certain graded skill levels, such as “basic technical skills for all, medium-level skills for many and high-level skills for a few” [7].

Provision of the basic technical skills, i.e. numeracy, elementary scientific skills and knowledge of elementary science in addition to literacy, usually comes under the realm of the primary education. Ensuring the attainment of these skills satisfactorily, i.e., in terms of both quantity and quality, requires the primary education to be universal and it to be backed by well-trained teachers in the relevant subjects, i.e. mathematics and science.

The medium-level skills may be provided through a variety of means, in the formal educational sector through secondary education and vocational training, to varying degrees. Referring to these two, there is some debate as to the most effective institution for delivering such skills [7] and the debate is not necessarily confined to the developing world. In the developed world, secondary schools accomplish this task to a satisfactory level, particularly in IT. However, there is no universal formula giving the right mix of these two kinds of institutions for a particular country. Considering the resource constraints that the African developing countries normally experience, it is a matter of optimising the available resources to produce an adequate number of graduates, individually trained to the right skill-level and collectively to the right skill profile (range of skills), bearing in mind the costs (equipping the laboratories and workshops, teacher training) and benefits (quality of training, range of competences, graduate numbers) of spreading funds possibly across a larger number of secondary schools or concentrating the funds in a smaller number of specialised vocational training centres [7].

The highest level of skills is attainable only through tertiary (higher) education, that is, through universities and other institutions enjoying similar status. The number and the quality of tertiary educational institutions vary considerably from country to country in the developing world, depending on the priority attached in each country to higher education and the level of funding they attract. Given the expenditure levels in Africa in public education, mentioned in Section 6.1.2, it would be surprising if the same is not true in Africa, if not worse. With such funding constraints, a crucially important issue, particularly in the African context, is how well such institutions function from the perspective of knowledge and technology transfer. In this respect, though it needs to be substantiated through field work, there is ground to believe that the curricula of a significant number of such African institutions may not have the right subject profile across specialisations and not

geared towards the knowledge transfer, particularly in relation to ICT. For example, as is shown in **Error! Reference source not found.**, many tertiary educational institutions in Africa still concentrate on humanities, thus overwhelmingly catering for the demand in the civil service and the commercial sector for administrative personnel. In some African countries, the lopsided emphasis placed on technology, described in Section 6.1.7, is a consequence of continuation of the academic traditions prevalent during the colonial times, while in others it is, perhaps, due to a lack of proper appreciation of country's economic goals. Therefore, there is an urgent need in these African countries to examine closely the academic content of curricula of the higher educational institutions and to make sure that they reflect accurately the demands of the economy and, in particular, structural changes foreseen by a modern knowledge-based economy.

Turning in particular to the needs of ICT-based industries, the higher educational institutions in Africa need to consider in their curricula subject areas such as Information Technology, computer science, telecommunications, and electronics and electrical engineering as possible specialisations. Obviously, this requires serious ground work before, or in the first year or two of, higher education in the areas of science and mathematics. Furthermore, the courses should be modern and up to date with the-state-of-the-art in each subject area and carry distinctly practical flavour with a strong practical and problem-solving element and emphasis on hands-on experience. Experimental, simulation and computational skills, practical skills in using industry-standard tools and databases, an appreciation of domain specific knowledge such as in health care, commerce, public services, etc., are to be expected as part of formal higher education in ICT [15]. The courses should conform to the required professional expectations of the practitioners, by ensuring that the graduates are well conversant with modern industrial tools and methodologies, are aware of ethical and legal matters as they relate to the profession, and are familiar with national and international requirements on intellectual property rights. They should have the built-in capability evolve over time by being able to adopt new knowledge and techniques and to adapt to changing economic and social circumstances. The course content and delivery should aim for accreditation by appropriate professional organisations.

7.2. Human Capital Development outside Formal Education

With respect to human resource development through training outside formal education, our concern is primarily higher-level skills and technology-specific forms of training. The providers of training outside the formal educational sector include the government and private sector R&D laboratories and other ancillary institutions (see Section 4.3), on-the-job training provided by foreign and domestic suppliers and firms (see Section 7.3 below), government departments, and engineering and management consultants [35].

The current state of vocational training provided outside the formal education by the private sectors is poorly understood. According to a World Bank survey, about 60% of firms provide some formal training in East Asia and Latin America [16]. However, there are disparities: with high and low training incidences: 76% firms in Singapore and in Philippines, 65% in China, 46% in Indonesia and 29% in Malaysia.

Despite their beneficial aspects, compared to the formal training offered by formal educational establishments, such training suffers from major drawbacks, in particular, the lack of an independent form of quality control with respect to the course content and delivery, the ad-hoc nature of training courses, the determination of the course content by the immediate needs of the organisation or the firm concerned, etc. However, the governments can set up a more formal framework for regulating the delivery of such training and be directly involved in order to influence the nature of such training and to make sure that they are in line with country's economic objectives. Incentive structures aimed at both personnel and providers of training can significantly boost the effectiveness of such training

[34]. They may include material incentives for personnel in the form of rewards and extra income for gaining additional qualifications and tax concessions and similar incentives to providers for widening the scope and depth of training.

7.3. Learning by Doing

The opportunity to learn by doing is open at all levels, from positions of apprenticeships to experienced professionals. At lower levels of training, it has the attraction of non-formality and suits particularly those who prefer learning by immersion and through direct involvement. At higher levels, it allows experienced professionals to reflect and innovate, thus enriching their experiential knowledge.

With the growth of ICT, whether due to indigenous ICT firms or driven by inward flow of FDI and influx of MNEs, learning by doing becomes a viable mode for raising the competence of ICT workforce extensively. Among the ones likely to receive more training from MNEs are the high-skilled, educated, better-paid workers and managers [24], explaining why learning by doing tends to have a significant effect on innovation and productivity. ICT being a fast-moving technology and practice in ICT often being ahead of the theory and what is taught at universities and technological colleges, learning by doing is an essential mode of learning in ICT and is perhaps the only means in keeping abreast with technological advances. In addition to learning through production processes, learning may take place also through activities, for example, marketing and investment in physical equipment.

7.4. Critical Mass of ICT Human Capital

In order for ICT to make an impact on the economy that is sufficient to tip the balance in favour of turning it into a knowledge-based economy, it is necessary that African countries ensure, firstly, that there is a critical mass of ICT professionals who are capable of supporting effective use of ICT across the spectrum of economic and social activities, that they have the means and incentives to pool their expertise as and when necessary, and that in turn they are supported by professional organisations and appropriate scientific establishments (universities, research institutions, etc.). The role of the latter is particularly important since it is they who eventually enable the country to stay ahead in the ICT industry through leading research and innovation.

ICT is a technology that permeates through every industry and commercial or other human activity, requiring all professionals to be competent in ICT skills as a user, or a creator, to an extent that is second only to their first speciality, whether one is a scientist, a banker, a medic or a librarian. Therefore, for effective utilisation of ICT in such activities it is necessary that professionals in such areas with the necessary ICT skills to an appropriate level of competence.

7.5. Effect of ICT on Employment and Skill Upgrading

The growth of ICT itself can have an effect on mobility within employment and, though it, on the constitution of human capital in terms of skills. The following are some observations drawn from US experience and are provided solely as evidence, rather than as a source that could be necessarily relied upon in drawing conclusions in the African context.

Whilst alluding to the need for better insights into skill upgrading as well as deskilling, the National Science Foundation's *Science & Engineering Indicators* [18] draws attention to several important findings, or observations, made by various studies devoted to the impact of IT on employment in the US. These are

- Computerisation of the workplace widens the gap between the incomes of those with a college [higher] education and those with a high school [secondary] education or less.
- It is difficult to isolate the net effect of IT on aggregate employment because of its conflicting influence in labour creation, especially in new knowledge-intensive industries, and labour saving, and due to other factors such as business cycles, industry conditions and labour mobility.
- Employment in IT producing industries was predicted to nearly double over the period 1986-2006, though this was entirely due to employment demand in computer and data processing services, which outstripped that in the other related industries by over a four-fold increase, the equivalent figures for other industries being 0.7 for computer and office equipment, 0.86 for communication equipment and 1.15 for electronic components.
- Though the development of IT is accompanied simultaneously by deskilling as well as skill upgrading, the different studies suggest that there is no overall deskilling effect and skill upgrading is considered widespread.
- In addition to there being a greater demand for workers with analytical capability and cognitive skills in handling information compared to those with data entry and data collating capabilities, the employment among the managerial, professional and technical personnel tends to grow faster compared to unskilled and semi-skilled workers.
- An important factor that drives the demand for skilled labour is the rapid skill upgrading in computer-intensive industries (i.e. those with the highest levels of computer investment per worker and attracting most workers with computing skills, and those with the largest share in overall investment)
- The industries with largest computer use tend to experience a shift in employee mix towards more managerial and professional staff from administrative and support staff.

It is interesting to note that deployment of computers for information processing results in some mobility within employment with an effect on associated skills and the effect of intensity of computer investment on the demand for skilled labour. These are indicative of secondary effects of ICT investment on the form and, to a lesser extent, the nature of the human capital.

8. Methodology

This section proposes the kind of information that needs to be gathered as part of the proposed country research on human capital development efforts of individual African countries, and outlines how it is to be synthesised and evaluated. Human capital development being a collective effort led by a tri-partite partnership involving the government, the academia and the industry, it is important to examine how effectively each of these agents performs its role in each country covered by the study.

The objective of this exercise is to establish human capital indicators, similar to those discussed in Section 5.2, but more specialised for assessing the maturity of human capital in terms of ICT capability to meet the needs of a country striving to become a knowledge-based economy. Obviously, if to be accomplished properly, this needs to be undertaken as a national effort, therefore encompassing, amongst others, education at all levels. This is obviously a huge task and is unlikely to be within the scope of the proposed project.

Therefore, a simplified approach is proposed here, concentrating more on tertiary education and other forms of specialised education, discussed in Sections 7.1-7.3, and to a limited extent on secondary education. For curtailing the scope, this study does not cover primary education.

The majority of human capital indicators discussed in Sections 5.1 and 5.2 are based solely on quantitative data such as student enrolment rates and numbers of R&D workers. An exception is the

work [17], which attempts an assessment of the quality of education by means of a ‘competitive educational index’, designed to give a measure of the appropriateness of country’s educational system for meeting the demands of a competitive economy. It was based on a survey of responses by 2500 senior executives.

We consider the quality of education as an important attribute in assessing how well the object under study, whether it is an academic department or a company training office, is equipped to serve the task of building an ICT-driven economy. However, our approach will differ from that used in [17] in several ways. Firstly, it will not be based on responses by executives or other personnel to a simple questionnaire, though such a questionnaire-based approach could be a part of it. Our approach will be based primarily on fieldwork, whereby researchers will gather the required information by a variety of means such as consultation of course documentation, published examination results, interviewing teachers, professors, university administrators, government officials and company directors, and using any other information available on the ground. Secondly, it will gather both quantitative and qualitative data and information from the relevant sources in a systematic manner. The information to be sought will be carefully selected so that a) it focuses on ICT capability assessment, and b) its amount is manageable and sufficient for the purpose.

Important Note: The information listed below under different headings from Section 8.2 onward is only tentative and indicative at this stage. This is to be revised in consultation with AERC.

8.1. A List of Countries for Case Studies

Below is a list of countries proposed for detailed ‘country studies’. They cover several regional categories, reflecting also the colonial backgrounds to a limited extent. The list does not reflect any rank order. The countries to be chosen would depend on the number of countries that the project is aimed at, as well as on the availability of researchers in the countries concerned, though it makes sense to choose at least one country from each category.

Anglophone Western Africa: Ghana
Nigeria

Francophone Africa: Mauritius (also an Anglophone country and an Indian
ocean state)
Cameroon
Ivory Coast
Burkina Faso
Senegal

East Africa Kenya
Tanzania
Ethiopia
Uganda

Central Africa Rwanda

Southern Africa South Africa

Zambia
Botswana
Namibia

8.2. Information to be Gathered on Tertiary (Higher) Education in ICT

The information to be gathered should address both quantitative and qualitative criteria. The relevance of the proposed quantitative data is perhaps self-evident. On the other hand, the qualitative data are aimed at forming an overall picture of the institution concerned based on the competence of teaching staff, their familiarity with the latest technical know-how, the academic standards, the academic QA procedures, the learning environment, and so on. A higher score on these criteria would give greater credibility to student attainment levels. In addition, competence of academic staff in research would give a higher score to country's R&D capability.

This will be limited to a representative sample of tertiary educational institutions drawn from a range of performance levels in ICT.

8.2.1. Learning and Teaching

Quantitative information:

- a) Enrolment and graduation numbers in ICT related courses, their comparison against other disciplines (engineering, business studies, law, medicine, humanities, etc.), the relationship of actual numbers with the those required for industrial needs and the institutional capacity
- b) Annual enrolment and graduation growth rates in ICT related courses
- c) Staff/student ratio, its comparison against the same in other disciplines, its growth in time and in relation growth in student numbers
- d) Destinations of graduates in ICT and related courses
- e) Plans for expansion of ICT courses to meet increasing demand

Qualitative information:

- f) Academic qualifications of staff (academic and professional)
- g) Curriculum and syllabus (subject profiles, pre-requisites and post-competences or learning outcomes)
- h) Academic standards (examination procedures including moderation, external examiner reports)
- i) Academic quality assurance (student and staff evaluation of courses, actions taken in response)
- j) Learning environment (stock of academic books and other literature in libraries, laboratory facilities: hardware and software)
- k) Accreditation of degrees by national and/or third country professional bodies

8.2.2. Staff and Departmental Research

Quantitative information:

- a) Publication output (scientific papers, academic books and other scholarly articles produced by the academic staff)
- b) Numbers of research students registered for higher degrees and their graduation rates
- c) Research grants (the numbers, amount of funds, the number of staff employed in each)
- d) Industrial consulting activities

Qualitative information:

- e) Subject profiles of publication output

- f) Citation by external authors of publications by academic staff
- g) Independent evaluations of research grants on completion
- h) Collaborations with external and international institutions

8.2.3. *Contribution to Professional Development*

Professional development activities are required to assess the learning by industrial workers, in conjunction with activities listed in Section 8.4.

Quantitative information:

- i) Industrial courses given and their subject areas
- j) Incidence and intensity
- k) Attendance levels
- l) Employment/company distribution of attendees

Qualitative information:

- m) Subject areas
- n) Prerequisite (attendee) qualifications and learning outcomes
- o) Feedback by attendees

8.3. *Information to be Gathered on Secondary Education in ICT*

This will be limited to a small representative sample of secondary schools to be agreed locally within each country and will be confined to learning and teaching aspects

Quantitative information:

- a) Enrolment numbers of students
- b) Student numbers attending ICT classes and the proportion of students taking ICT as a subject in final examinations
- c) Student numbers attending science classes and the proportion of students taking science as a subject in final examinations
- d) Staff/student ratio in ICT classes
- e) Destination of students on completion of secondary education (specially, student numbers entering ICT courses, and ICT-related courses, at tertiary educational institutions and at vocational institutions)

Qualitative information:

- f) Academic qualifications of staff teaching ICT (teacher training, qualifications in ICT or sciences)
- g) Place of ICT and science in the curriculum and syllabus
- h) Academic standards (examination bodies and procedures)
- i) Learning environment (library facilities for ICT, laboratory facilities: hardware and software)

8.4. *Information to be gathered on MNEs and FDI*

Quantitative information:

- a) Incidence, intensity and the type of training provided by MNEs and domestic firms
- b) Beneficiaries of training
- c) Source of finance for training
- d) Government activities in support of such training activities
- e) Growth rate of inflow of MNEs and FDI over time

- f) Survey of the forms of MNE inflow (e.g. mergers and acquisitions (through equity acquisition in private companies and privatisation of public enterprises) verses Greenfield investment (new capital investments though newly formed subsidiaries))

Qualitative information:

- g) The nature of training (operational training, higher-order training activities: design and manufacture, management, planning, etc.)
- h) Identification of specific areas of knowledge targeted by the training activities for knowledge transfer
- i) Effectiveness of government role in MNE-driven training activities
- j) Evidence of a virtuous circle of human capital formation and increased inflow of MNEs

8.5. *Information to be Gathered from Government Officials*

Quantitative information:

- a) Government budget on ICT education at tertiary education, absolute as well as relative to the overall budget in tertiary education
- b) Government budget on ICT education at secondary education, absolute as well as relative to the overall budget in secondary education
- c) Government targets on ICT graduates, absolute as well as relative to the targets in other subject areas
- d) How the above are met nationally
- l) Plans for expansion of ICT education and training to meet increasing demand
- e) Leading academic institutions providing ICT education and their funding levels for ICT
- f) Distribution of ICT educational budget across institutions in (d) above
- g) The companies with which the government liaises regarding ICT education both within formal educational system and within the industry
- h) A list of educational activities provided by the industrial sector

Qualitative information:

- i) Government ICT policies and programmes, if any
- j) Student admission criteria for different tertiary educational institutions
- k) Policies in quality assurance in teaching
- l) The nature of educational activities provided by the industrial sector
- m) Government support for research within ICT departments

8.6. *Synthesis and Evaluation*

From an analytical point of view the above constitute a list of quantitative and qualitative attributes, respectively with numerical and non-numerical values, on tertiary education, secondary education, training provided by industrial organisations and private companies and government role in education and training. Our aim is to cluster these attributes into number of groups, so that each group signifies one of the following aggregate attributes.

- a) Academic standard of graduates in ICT and ICT-related disciplines upon completion of studies (knowledge, competence, professional accreditation, employability)
- b) Sufficiency of graduates in ICT and ICT-related disciplines to meet industrial needs nationally
- c) Opportunities for high quality professional development for ICT workers in industry
- d) R&D capacity in ICT departments (and elsewhere, if applicable) and their performance

- e) Sustainability of required ICT education (national expenditure, commitment, teacher training, maintenance of a suitable learning environment, expansion of education and training with expanding role of ICT in economic development)

Each one of them will be mapped to values on an appropriate numerical scale. The above set of aggregate attributes should produce a profile of each country's ICT capability. In most cases, this should be an adequate measure of the overall performance of a given country in ICT capability. However, if necessary, a single overall numerical score may be derived for the complete set of attributes by taking a weighted sum of the values of the above aggregate attributes. The approach to be followed in arriving at (a)-(e) above, or a single overall numerical score, would be similar that followed by United Nations agencies in deriving HDI, mentioned in Section 6.1.1; see [32].

It would have been ideal if the proposed approach could be tested first on a number of countries, the ranking of ICT capability of which is not in question. These countries may be drawn from both developing (outside Africa) and developed countries. If the approach produces the expected ranking, this would give some credibility to the broad validity of the approach.

Unfortunately, this is not possible as part of this project. Therefore, the analysis should be conducted by weighing the information not only quantitatively but also judiciously, constantly questioning the outcome of each step critically.

9. A Summary and Conclusions

Many countries in the developing world in Asia and Latin America are taking the achievements of ICT into great advantage in turning themselves into vibrant modern economies producing hi-tech goods and services, thereby bringing prosperity to their nations. This paper examined how to develop an ICT strategy for Africa, with particular reference to its human capital, in order to enable it to pursue a similar path of development. A specific task of this framework paper is to form a basis for several country studies aimed at establishing accurately the current state of the human capital in African countries in the area of ICT. Such detailed country case studies would be a significant input to formulation of policies directed at improving both the human capital of African countries with respect to ICT and their overall technological capability. This is essential if they are to position themselves better to implement ICT inspired economic strategies for the benefit of their own economies. Since not all the African countries have the economic capacity to have their own institutions, it make sense to develop sustainable ICT capability development policies for Africa establishing, for example, regional institutions to train the necessary ICT professionals and to support ICT enterprises and activities. Regional technical universities of excellence could be a part of such an institutional structure.

This paper begins with an overview of major issues related to human capital development in the African continent. The paper highlights the need for African governments first to develop a strategy towards the development of ICT with a view to securing the maximum benefits to the economy and, where feasible, transforming their economies into knowledge-based economies along the lines undertaken by some of the successful developing countries in ICT capability building. The paper points out to two possibilities for ICT capacity building: use of ICT applications for efficiency gaining and production of ICT goods for internal market and export, but emphasises their different roles in the economy. It also highlights the need for addressing knowledge gaps in the country by means of knowledge transfers and, at the same time, the need for addressing information problems so that those who really matter, i.e., the farmers, the industrialists and the entrepreneurs, have access to

information, enabling them to draw the maximum benefit from the available information for productive work and thus to drive the economy forward.

As human capital development is inextricably linked with capability development as the ultimate goal, it is essential to understand how they relate to, and enrich, each other. The paper examines different facets of this relationship, the dependence of technological capability and human capital on other capabilities such as technological and institutional infrastructure, the role of national governments in bringing about technology transfer, and various mechanisms of technology transfer. In this respect, the paper underlines the importance of the following:

- The need for a conducive socio-economic environment for founding a knowledge-based economy (macro-economic stability, favourable conditions for foreign investments, liberalisation of the telecommunication sector, good industrial relations, trade and financial liberalisation)
- The need for creating an advanced communication and technological infrastructure
- The need for creating an appropriate institutional infrastructure to support ICT technological capability (professional organisations, body for protecting IPR and patents; see Section 4.3)
- Development of human capital through education at all levels, especially in ICT and technological disciplines and training
- Promote innovation and R&D activities both within academia and industry
- The need for national commitment bound by a 'common purpose' and inspired by a visionary leadership
- Coordinated action on capability building with the full involvement of government, industry and academia

In pursuing technology capability development and human capital development, it is important to be able to measure progress and the effectiveness of the effort that a country puts into them. The paper examines some of the indicators produced for this purpose by public and international organisations and researchers in development studies. Using these indicators and the data available in the public domain, the paper then highlights the current state of human capital in Africa from a general point of view and draw attention to some of the notable weaknesses in human capital development, especially in terms of expenditure on education, literacy, the number of graduates in technological disciplines, etc., compared to other countries in the developing world which have made significant progress in the development of ICT to economic advantage.

In turning attention to country research aimed at establishing the current state of human capital from the point of ICT, the paper underlines the importance of paying attention to qualitative measures, in addition to the quantitative measures used in other more general studies on human capital development. The paper then proposes some tentative quantitative and qualitative attributes for gathering information through fieldwork of country studies on tertiary education, secondary education, training provided by industrial organisation and private companies and government role in education and training.

10. Bibliography and References

- [1] Adjibolosoo, Senyo B-S. K. (editor); International perspectives on the human factor in economic development. Westport, Connecticut. London. Praeger, 1998
- [2] Archibugi, Daniele and Coco, Alberto, A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo). (January 2004). CEIS Working Paper No. 44. Available at SSRN: <http://ssrn.com/abstract=487344>
- [3] Blomstrom, Magnus and Kokko, Ari.; FDI and Human Capital: a Research Agenda. Working Paper 195. Organisation for Economic Co-operation and Development (OECD), Paris. August 2002.
- [4] Chinien, Chris (UNEVOC-Canada); The Use of ICTs in Technical and Vocational Education and Training: Analytical Survey, UNESCO Institute for Information Technologies in Education (IITE), Moscow, 2003.
- [5] Cohen, Daniel and Soto, Marcelo; Growth and Human Capital: Good Data and Good Growth. Working Paper 179. Organisation for Economic Co-operation and Development (OECD), Paris. September 2001.
- [6] Digital Opportunity Initiative. Creating a Development Dynamic (Final Report), July 2001. <http://www.opt-init.org/framework/>
- [7] Eagle, Nathan. EPROM: Entrepreneurial Programming and Research on Mobiles for the Developing World. W3C Workshop on the Mobile Web in Developing Countries, Bangalore, India, December 5-6, 2006. <http://www.w3.org/2006/07/MWI-EC/cfp.html>
- [8] Enos, J. L. The Creation of Technological Capability in Developing Countries, Pinter Publishers, 1991.
- [9] Freeman, Chris; Interdependence of Technological Change with Growth of Trade and GNP; in Nissanke, Machiko and Hewitt, Adrian (eds); Economic Crisis in Developing Countries, Pinter Publishers, 1993
- [10] Goldstein, Andrea and O'Connor, David; e-Commerce for Development: Prospects and Policy Issues. Working Paper 164. Organisation for Economic Co-operation and Development (OECD), Paris. September 2000.
- [11] Gholami, Roghieh; Lee, Sang-Yong Tom and Heshmati, Almas. The Casual Relationship between Information and Communication Technology and Foreign Direct Investment, World Economy, January 2006.
- [12] Hilty, Lorenz M., Seifert, Eberhard K. and Treibert, Rene; Information Systems for Sustainable Development. Idea Group Publishing, 2005.
- [13] Kapstein, Ethan B.; Virtuous Circles? Human Capital Formation, Economic Development and Multinational Enterprise. Working Paper 191. Organisation for Economic Co-operation and Development (OECD), Paris. August 2002.
- [14] Lall, Sanjaya and Pietrobelli, Carlo. Africa's Technology Gap, Case Studies on Kenya, Ghana, Uganda and Tanzania, Joint Integrated Technical Assistance Programme (JITAP), Joint project by UNCTAD, the World Trade Organization and the International Trade Centre. UNCTAD/ITE/IPC/Misc.13. United Nations Publications, July 2003.
- [15] Mansell, Robin and Wehn, Uta; Editors, Information Technology for Sustainable Development, INK - Knowledge Societies, Oxford University Press, ISBN 0-19-829410-7, 1998
- [16] Miyamoto, Koji. Human capital formation and foreign direct investment in developing countries. Working Paper 211. Organisation for Economic Co-operation and Development (OECD), Paris. July 2003.
- [17] Nair, Mahendhiran and Kuppusamy, Mudiarasan. Trends of Convergence and Divergence in the Information Economy: Lessons for Developing Countries. The Electronic Journal on Information Systems in Developing Countries (EJISDC) 2004, 18, 2, 1-32. <http://www.ejisdc.org>

- [18] National Science Foundation, Science & Engineering Indicators – 1998, <http://www.nsf.gov/statistics/seind98/>
- [19] Nissanke, Machiko. Pro-Poor Globalisation: an Elusive Concept or a Realistic Perspective? (Professorial) Inaugural Lecture. Department of Economics, School of Oriental and African Studies, University of London. November 2006
- [20] Organisation For Economic Co-Operation And Development (OECD), Human Capital Investment – An International Comparison (online publication). Centre for Educational Research and Innovation 1998, <http://213.253.134.29/oecd/pdfs/browseit/9698021E.PDF>
- [21] Pissarides, Christopher A.; Human Capital and Growth: a Synthesis Report. Working Paper 168. Organisation for Economic Co-operation and Development (OECD), Paris. November 2000.
- [22] Pohjola, Matti (ed.). Information Technology, Productivity, and Economic Growth: International Evidence and Implications for Economic Development. WIDER Studies in Development Economics. Oxford University Press, 2001.
- [23] Pritchett, Lant. India Development Policy Review: Inclusive Growth and Service delivery: Building on India's Success – Overview – ; http://www.lpritchett.org/India_DPR_overview.pdf
- [24] Ritchie, Bryan K.; Foreign Direct Investment and Intellectual Capital Formation in Southeast Asia. Working Paper 194. Organisation for Economic Co-operation and Development (OECD), Paris. August 2002.
- [25] Sachs, Jeffrey D. and McArthur, John W.; Technological Advancement and Long-Term Economic Growth in Asia, in Technology and the New Economy by Chong-En Bai, Chi-Wa Yuen. 2003. pp 157-185.
- [26] SciDev.net; <http://www.scidev.net/quickguides/index.cfm?fuseaction=definitions&qguideid=6>
- [27] Slaughter, Matthew J.; Skill Upgrading in Developing Countries: Has Inward Foreign Direct Investment Played a Role? Working Paper 192. Organisation for Economic Co-operation and Development (OECD), Paris. August 2002.
- [28] Singh, Nirvikar; India's Information Technology Sector: What Contribution to Broader Economic Development? Working Paper 207. Organisation for Economic Co-operation and Development (OECD), Paris. March 2003.
- [29] Sleezer, Catherine M., Wentling, Tim L. and Gude, Roger L.; Human Resource Development and Information Technology: Making Global Connections. Kluwer Academic Publishers, 2002.
- [30] Tigre, Paulo Bastos and O'Connor, David; Policies and Institutions for e-Commerce Readiness: What can Developing Countries learn from OECD experience? Working Paper 189. Organisation for Economic Co-operation and Development (OECD), Paris. April 2002.
- [31] Tschang, Ted; China's Software Industry and its Implications for India. Working Paper 205. Organisation for Economic Co-operation and Development (OECD), Paris. February 2003.
- [32] UNDP Human Development Report, 2005, <http://hdr.undp.org/statistics/>
- [33] United Nations. Report of the World Commission on Environment and Development (or Brundtland Commission), 1987.
- [34] Virmani, B. R. and Rao, Kala; Economic Restructuring, Technology Transfer and Human Resource Development. Response Books, 1997.
- [35] Willem te Velde, Dirk; Government Policies for Inward Foreign Direct Investment in Developing Countries: Implications for Human Capital Formation and Income Inequality. Working Paper 193. Organisation for Economic Co-operation and Development (OECD), Paris. August 2002.
- [36] Wikipedia, the free encyclopedia, History of Indian Institutes of Technology. http://en.wikipedia.org/wiki/History_of_Indian_Institutes_of_Technology.
- [37] World Bank, Knowledge for Development, World Development Report, 1998/99.

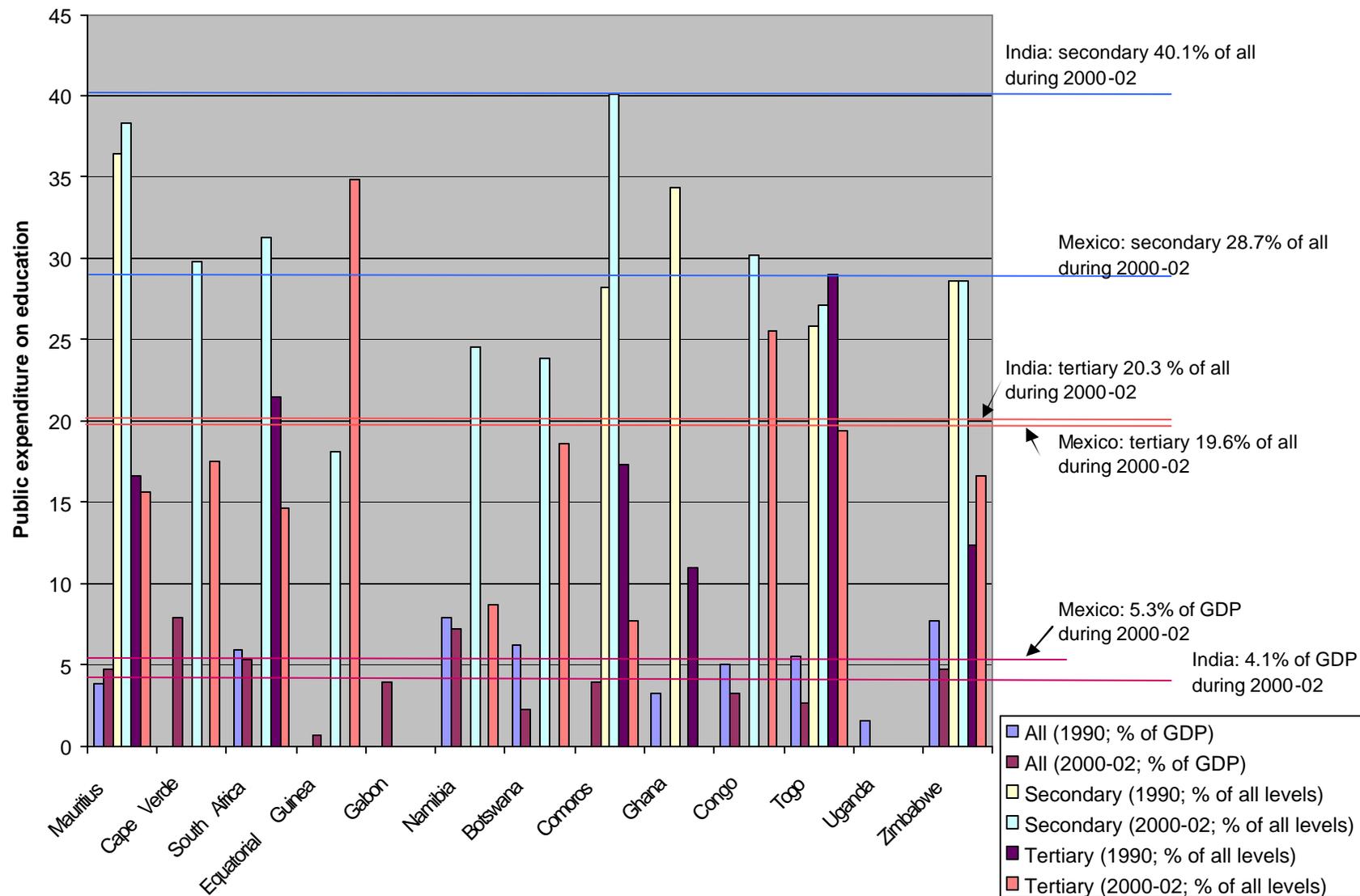


Figure 5. Public expenditure on education in African countries with Medium Human Development (Source: UNDP Human Development Report, 2006; [32])

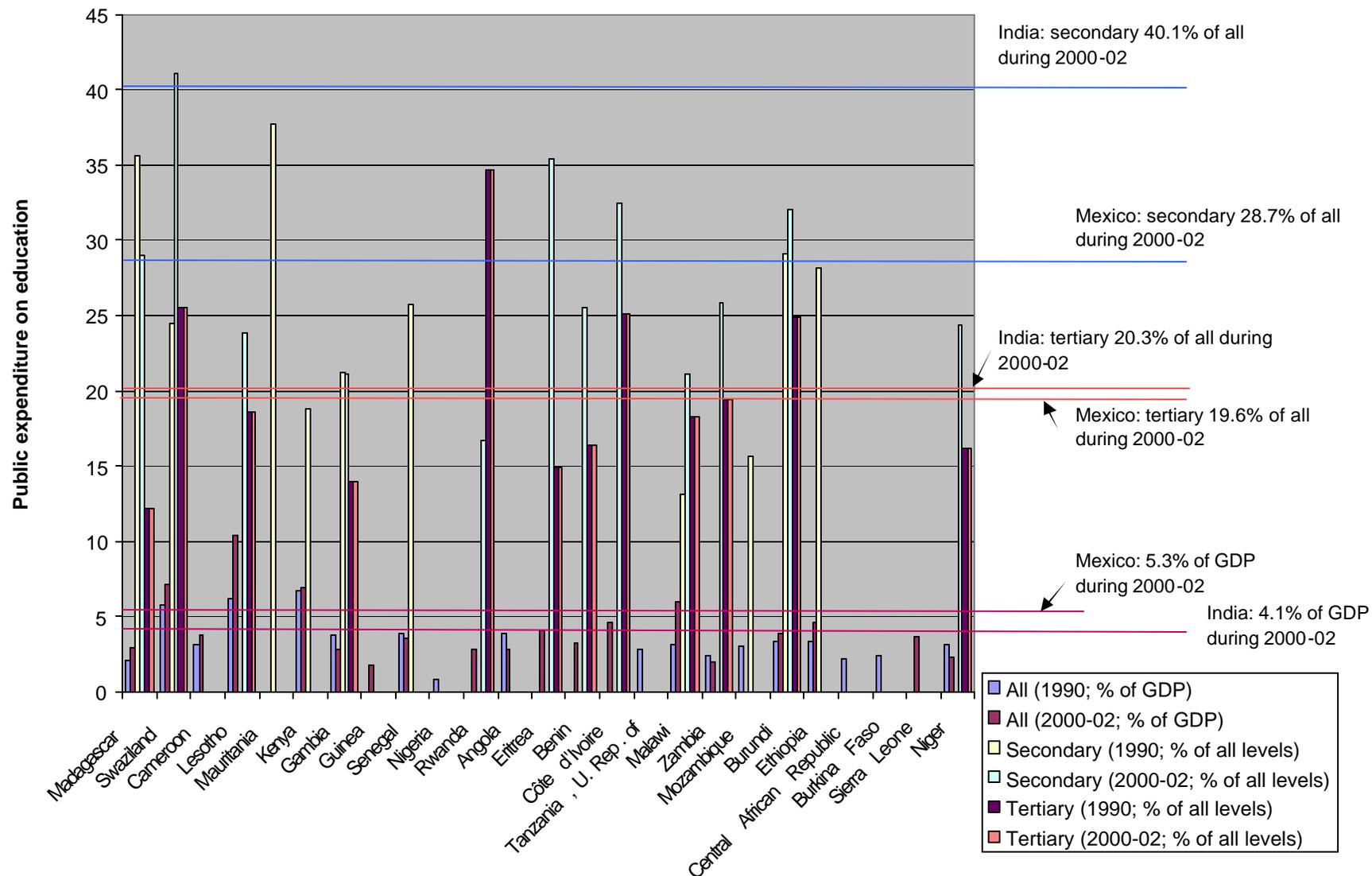


Figure 6. Public expenditure on education in African countries with Low Human Development (Source: UNDP Human Development Report, 2006; [32])

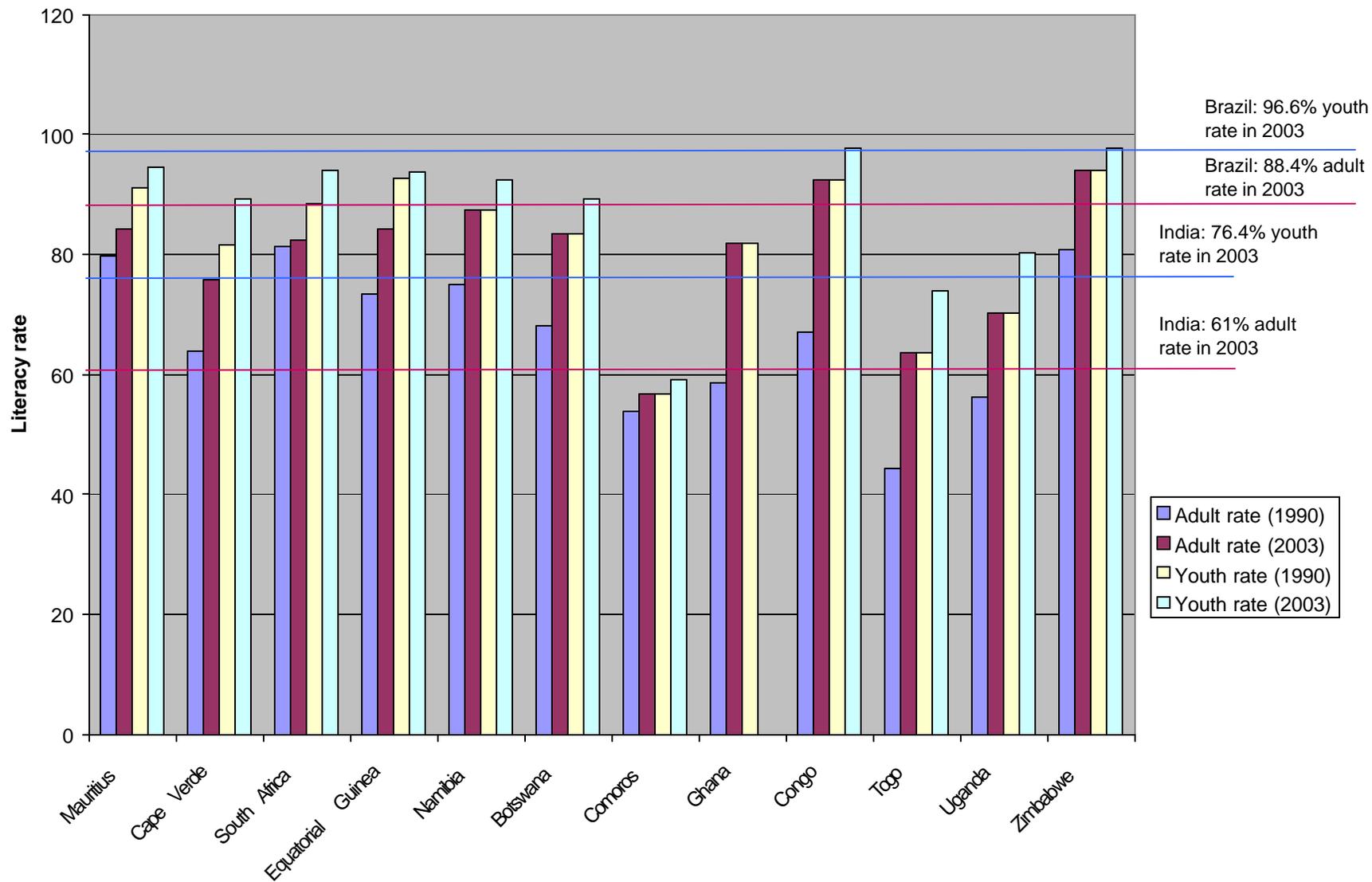


Figure 7. Literacy rates in African countries with Medium Human Development (Source: UNDP Human Development Report, 2006; [32])

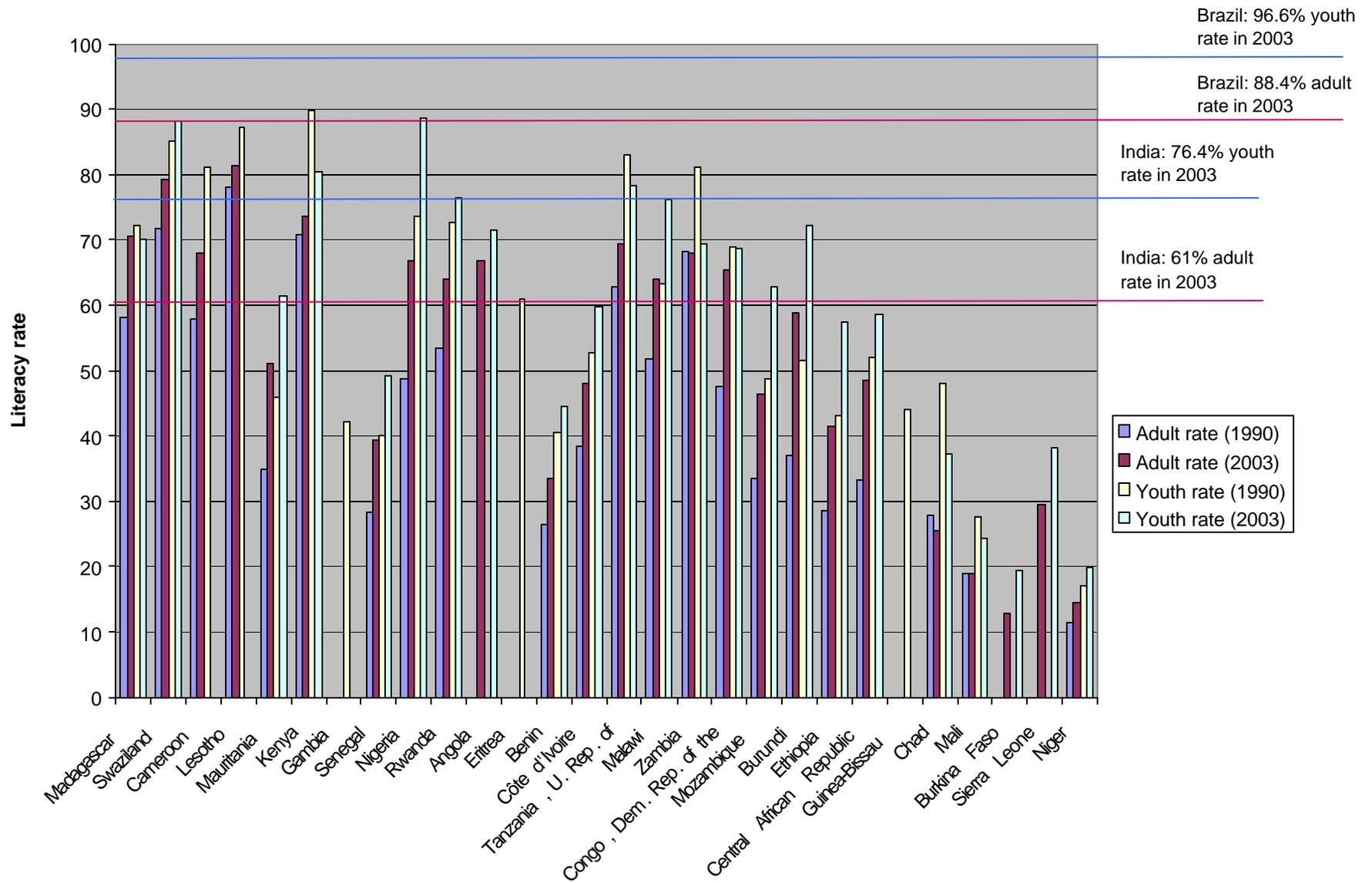


Figure 8. Literacy rates in African countries with Low Human Development (Source: UNDP Human Development Report, 2006; [32])

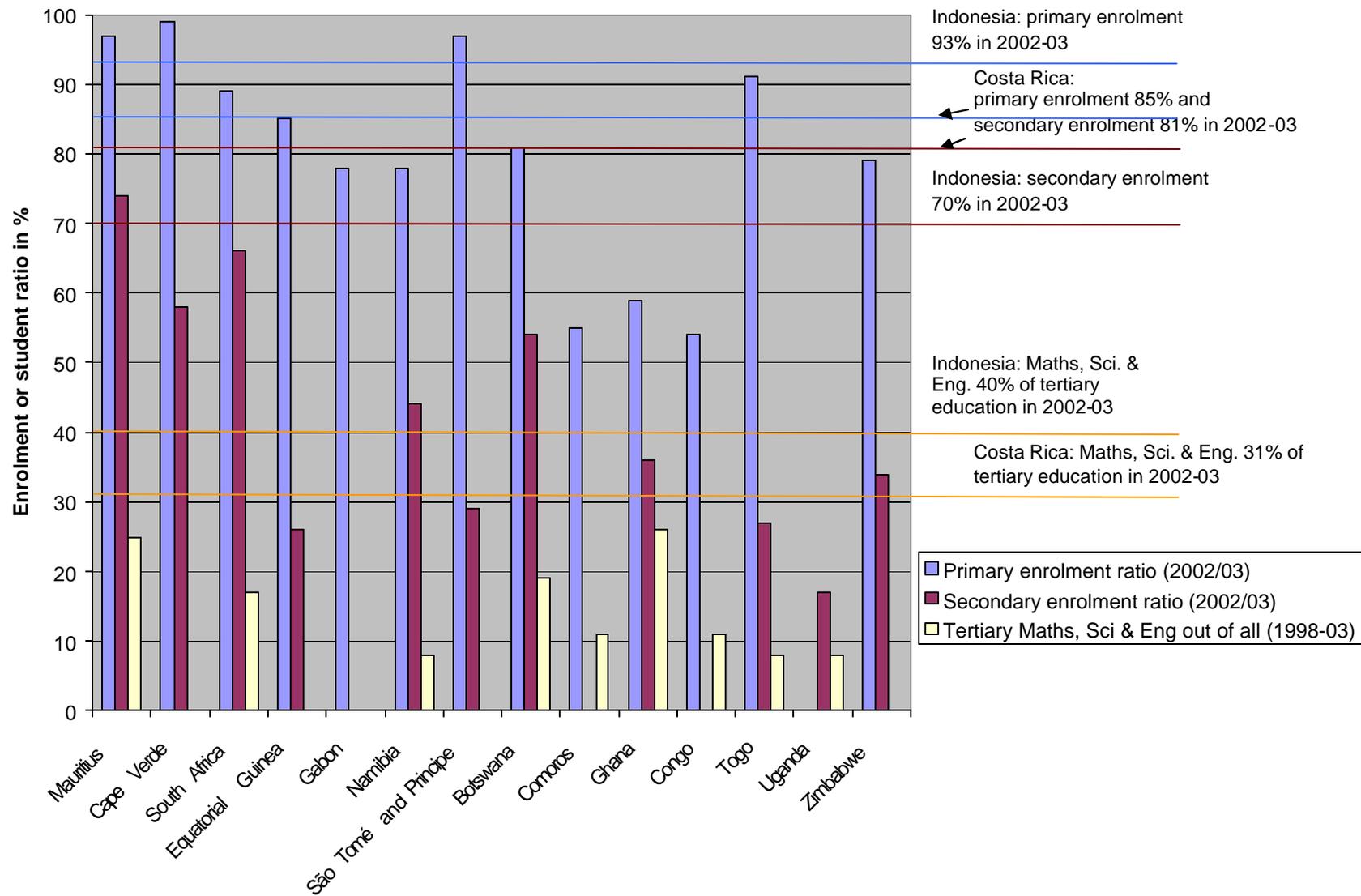


Figure 9. Primary and secondary student enrolment and student numbers in tertiary education in African countries with Medium Human Development (Source: UNDP Human Development Report, 2006; [32])

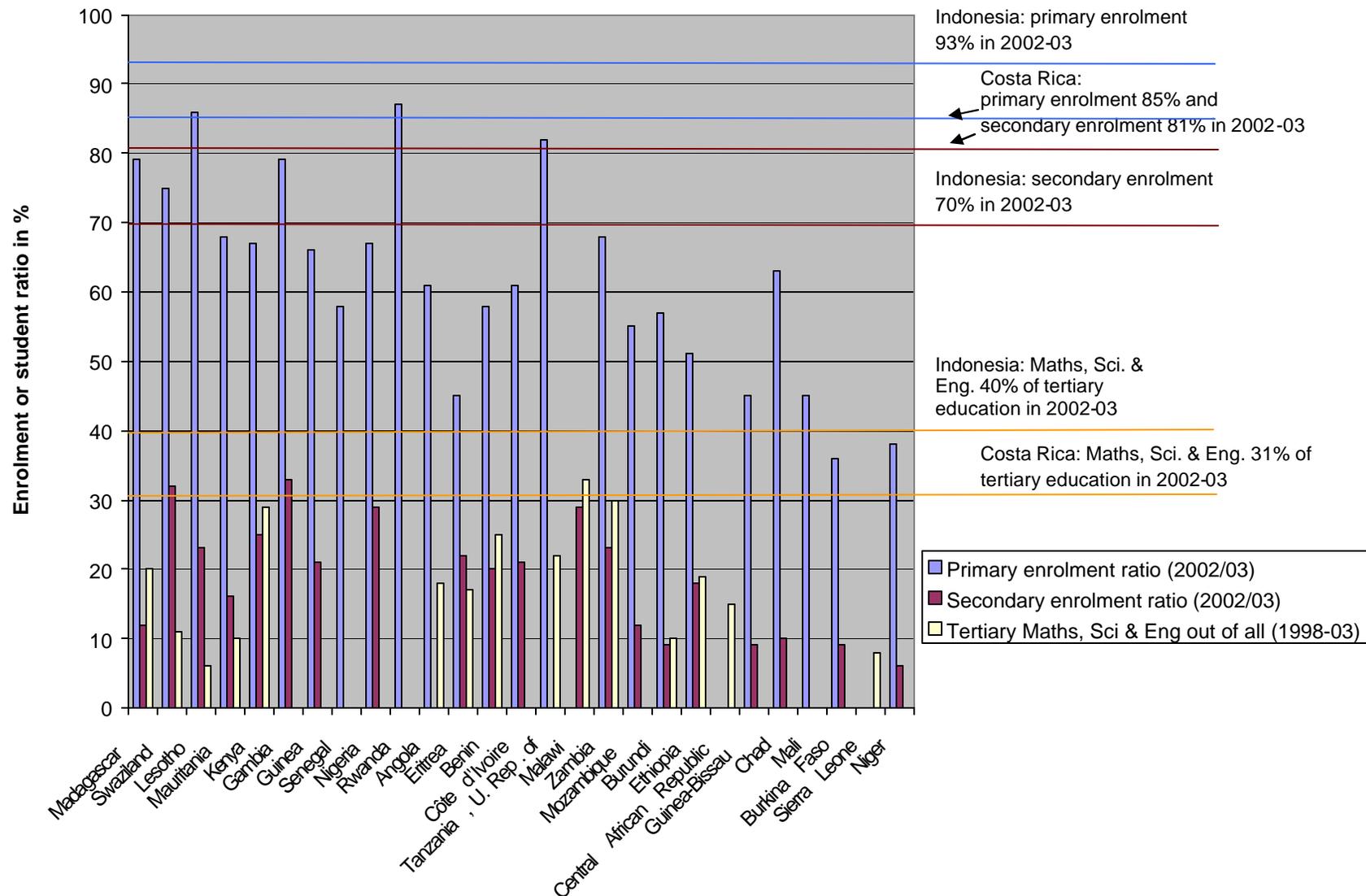


Figure 10. Primary and secondary student enrolment and student numbers in tertiary education in African countries low Medium Human Development (Source: UNDP Human Development Report, 2006; [32])

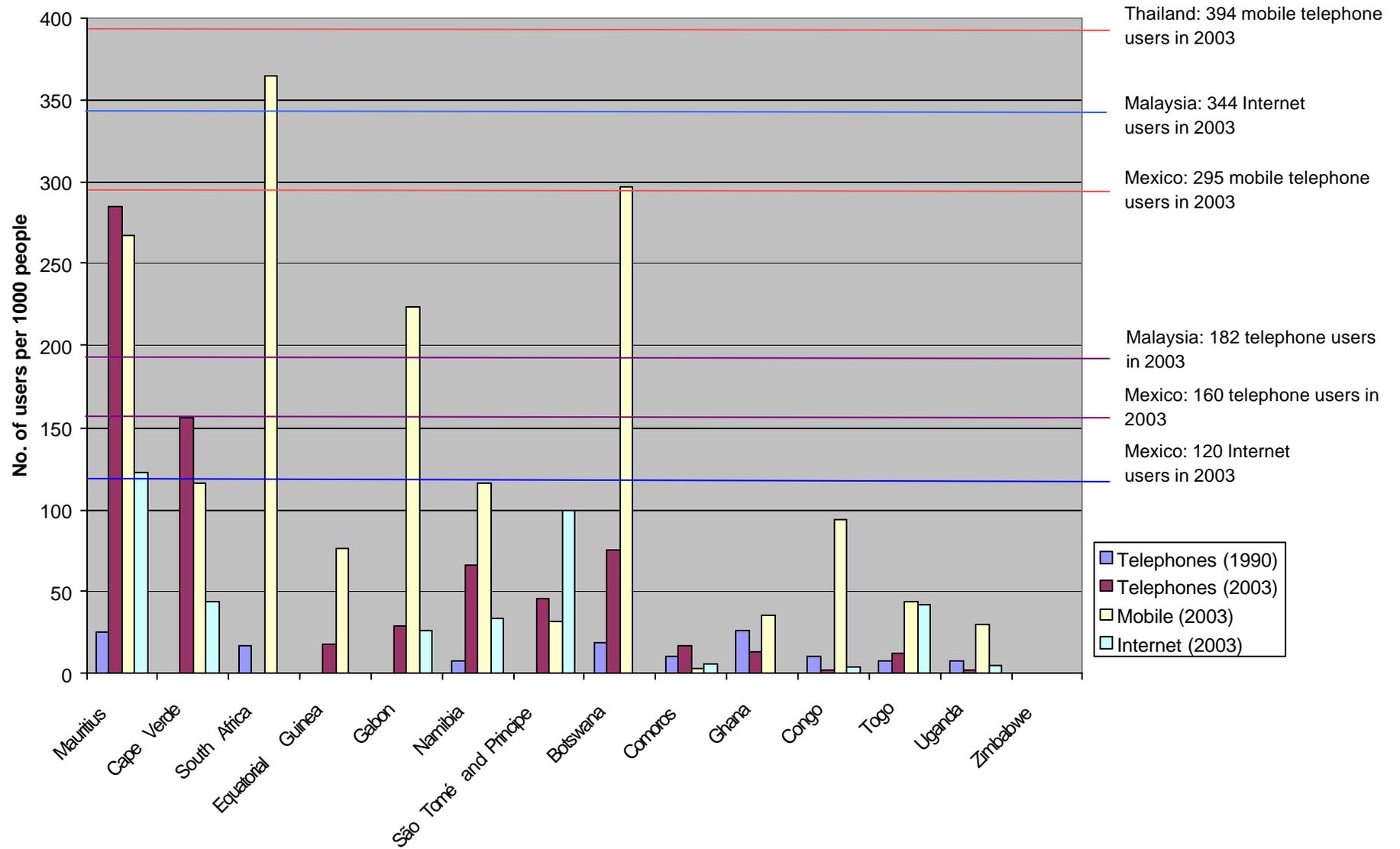


Figure 11. Use of communication technologies in African countries with Medium Human Development (Source: UNDP Human Development Report, 2006; [32])

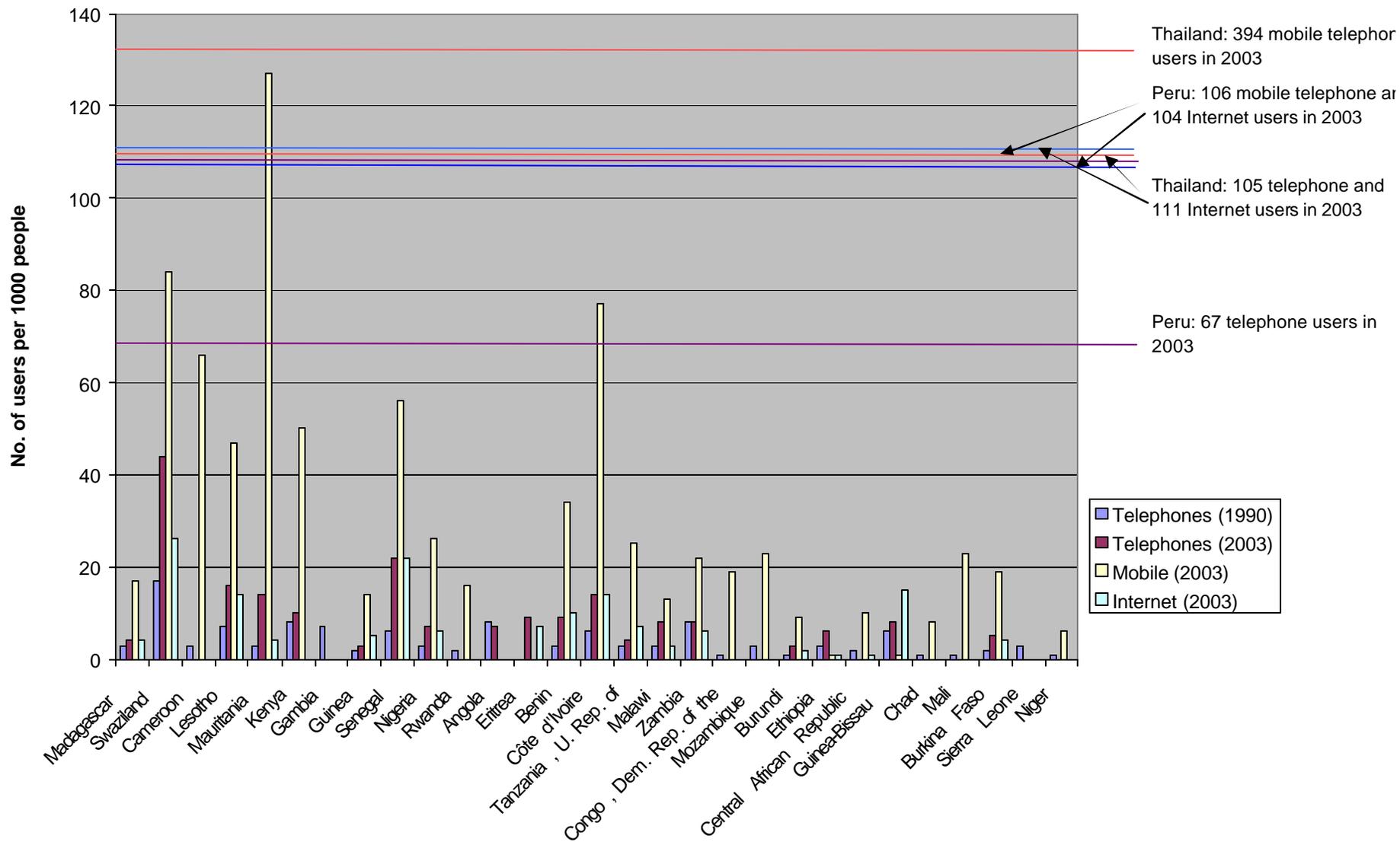


Figure 12. Use of communication technologies in African countries with Low Human Development (Source: UNDP Human Development Report, 2006; [32])

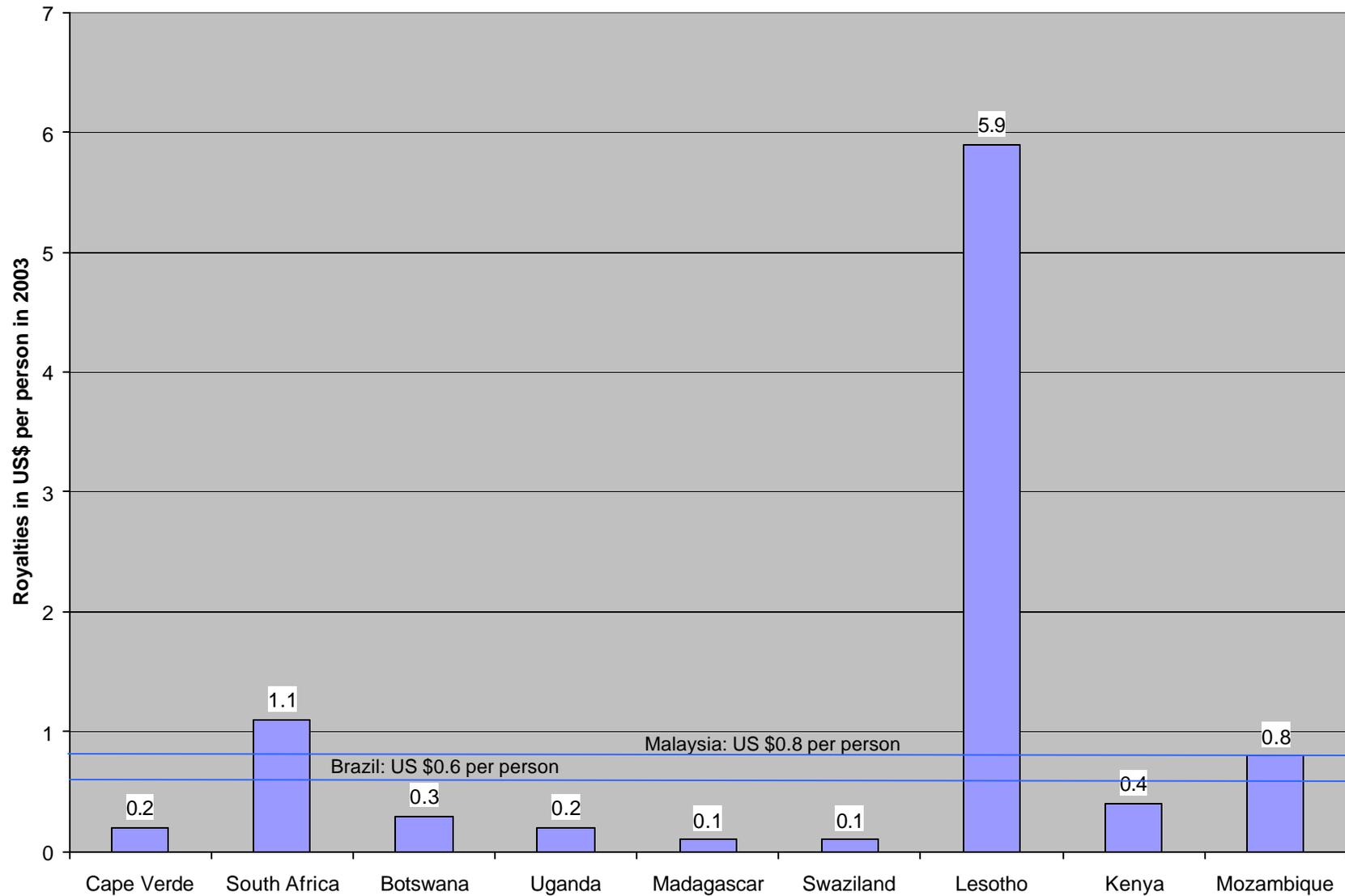


Figure 13. Receipts of royalties and license fees in African countries with Medium and Low Human Development (Source: UNDP Human Development Report, 2006; [32])

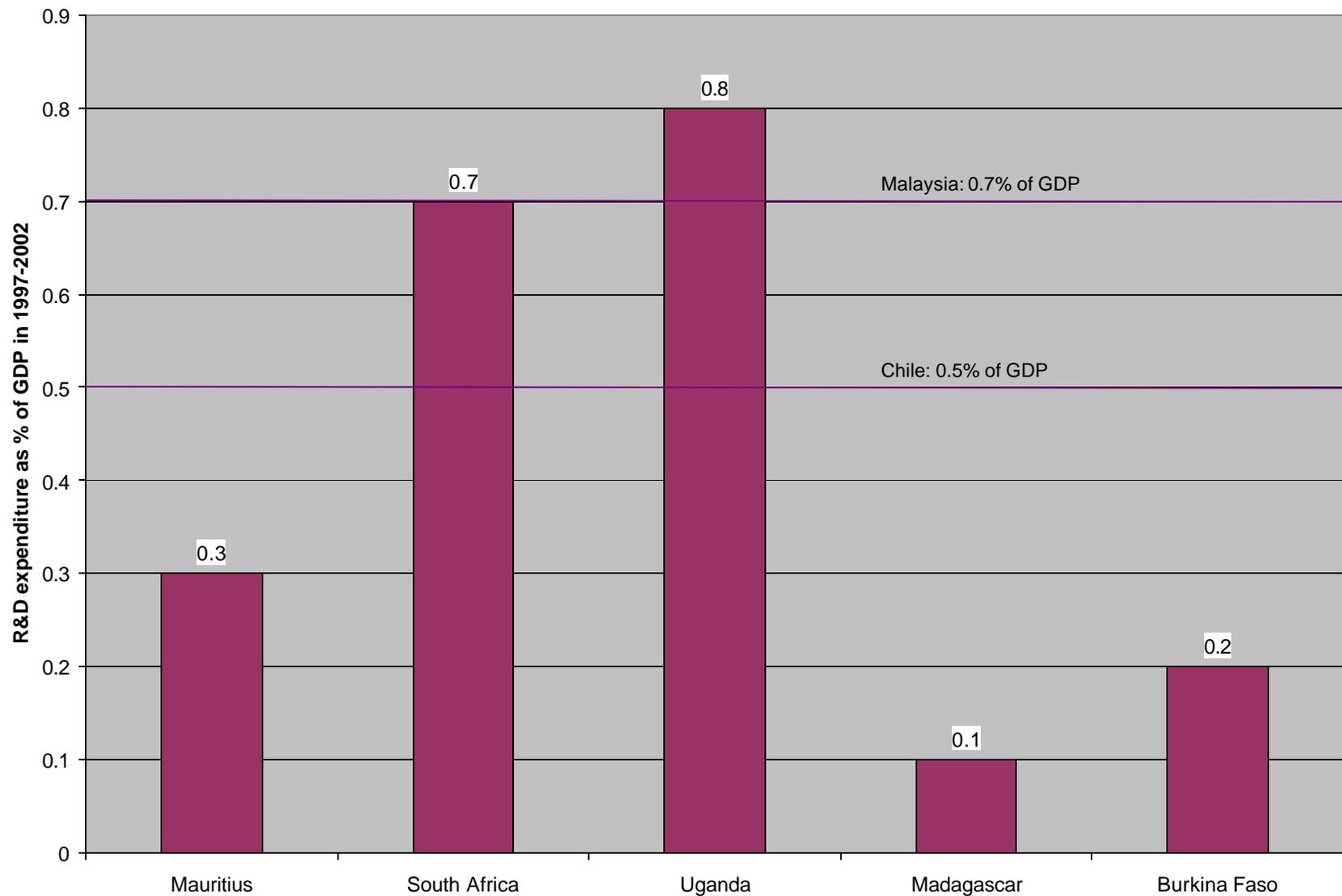


Figure 14. Research and Development Expenditure in African countries with Medium and Low Human Development (Source: UNDP Human Development Report, 2006; [32])

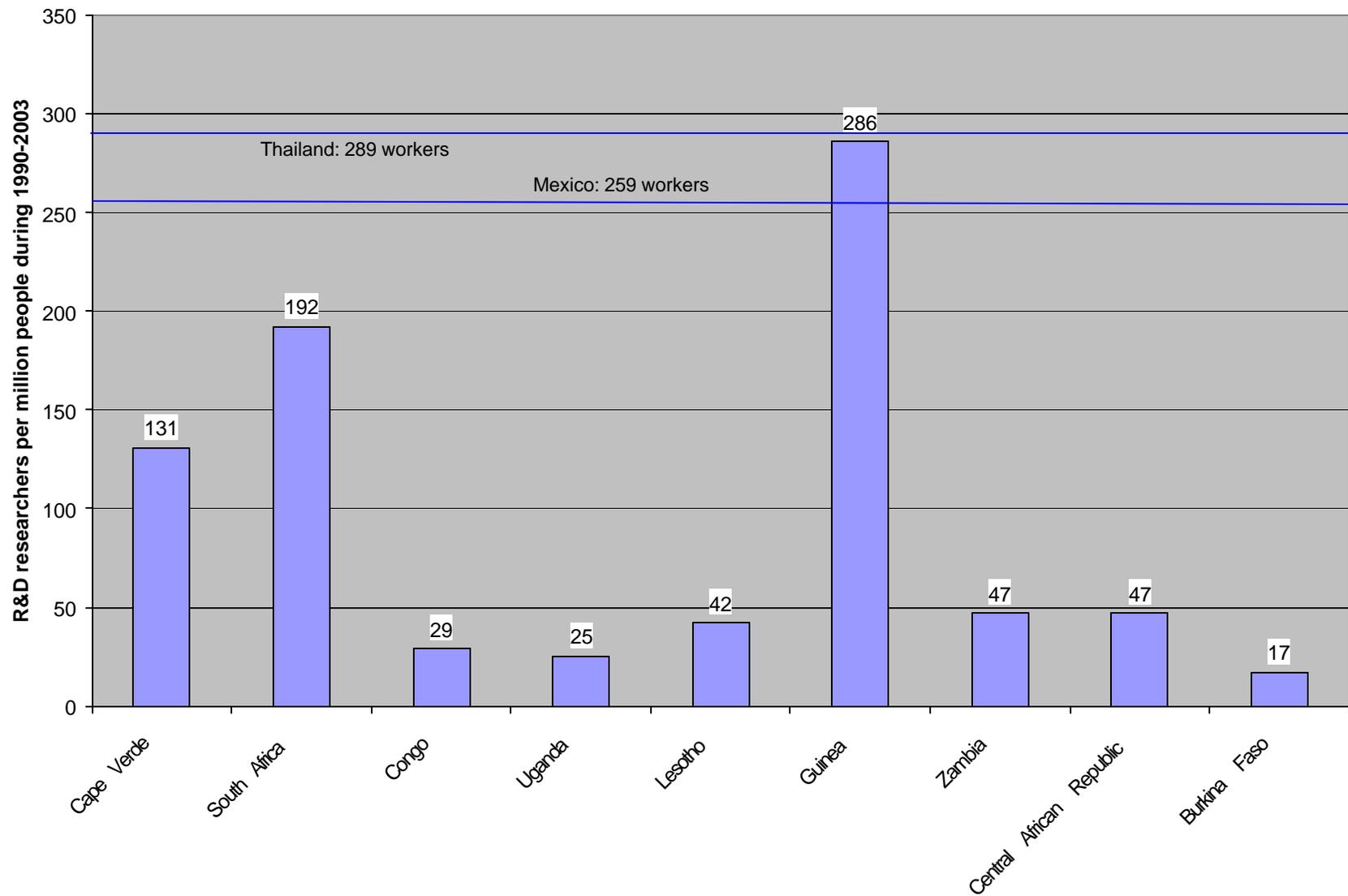


Figure 15. Researchers engaged in Research and Development in African countries with Medium and Low Human Development (Source: UNDP Human Development Report, 2006; [32])

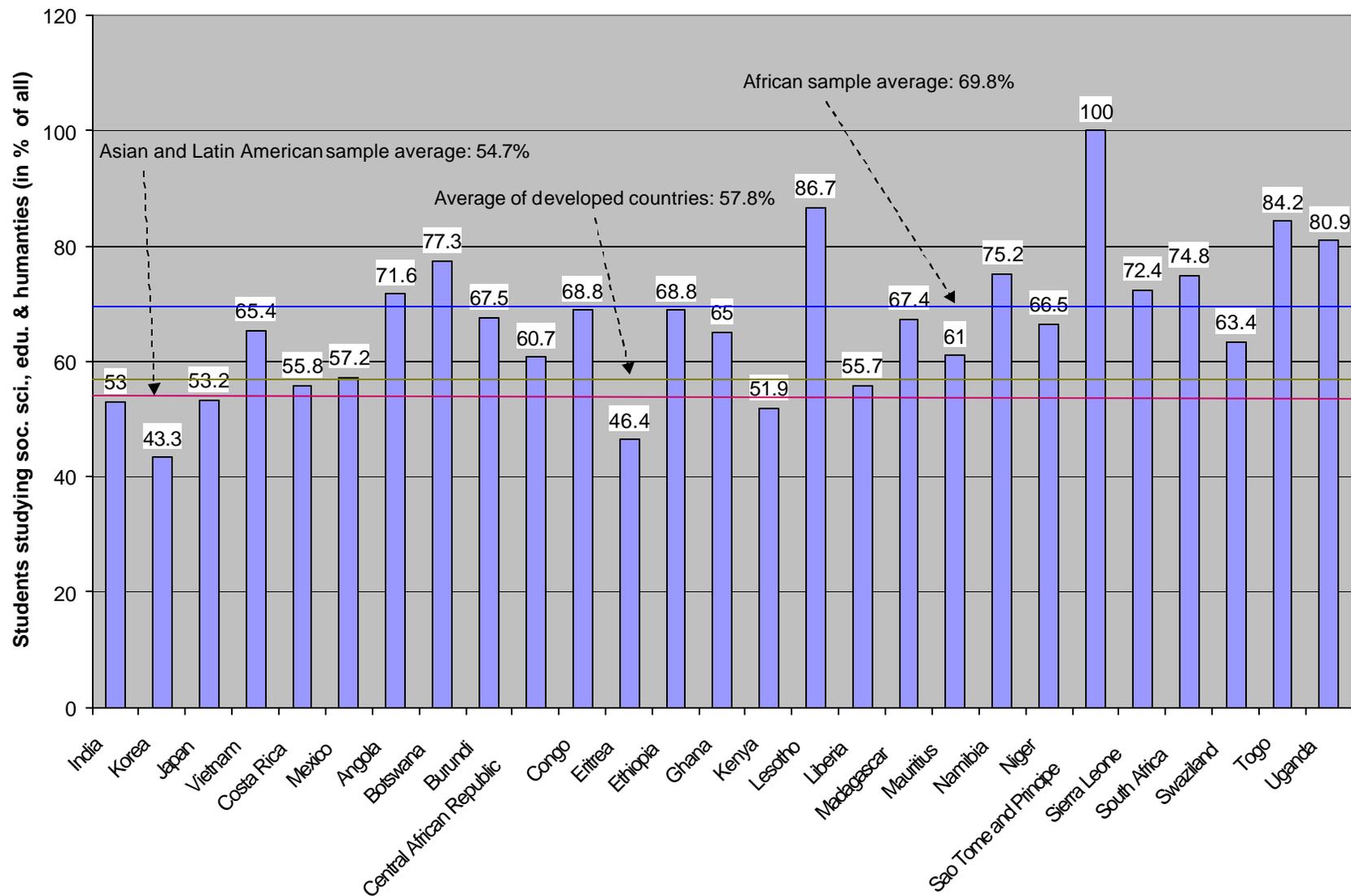


Figure 16. Students studying humanities, education, social sciences, business and law (Source: UNESCO Analytical Survey [4])

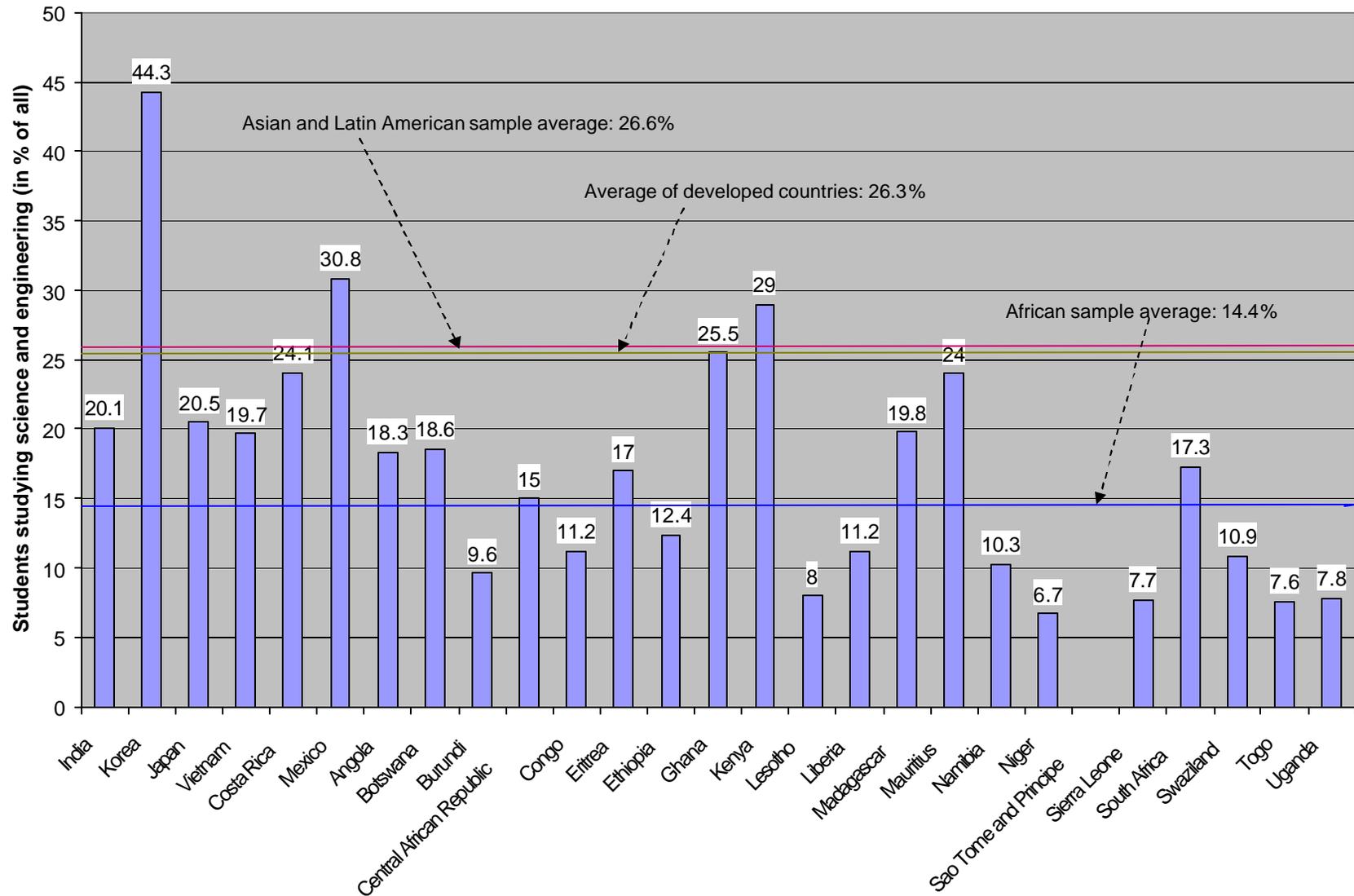


Figure 17. Students studying science, engineering, manufacture and construction (Source: UNESCO Analytical Survey [4])

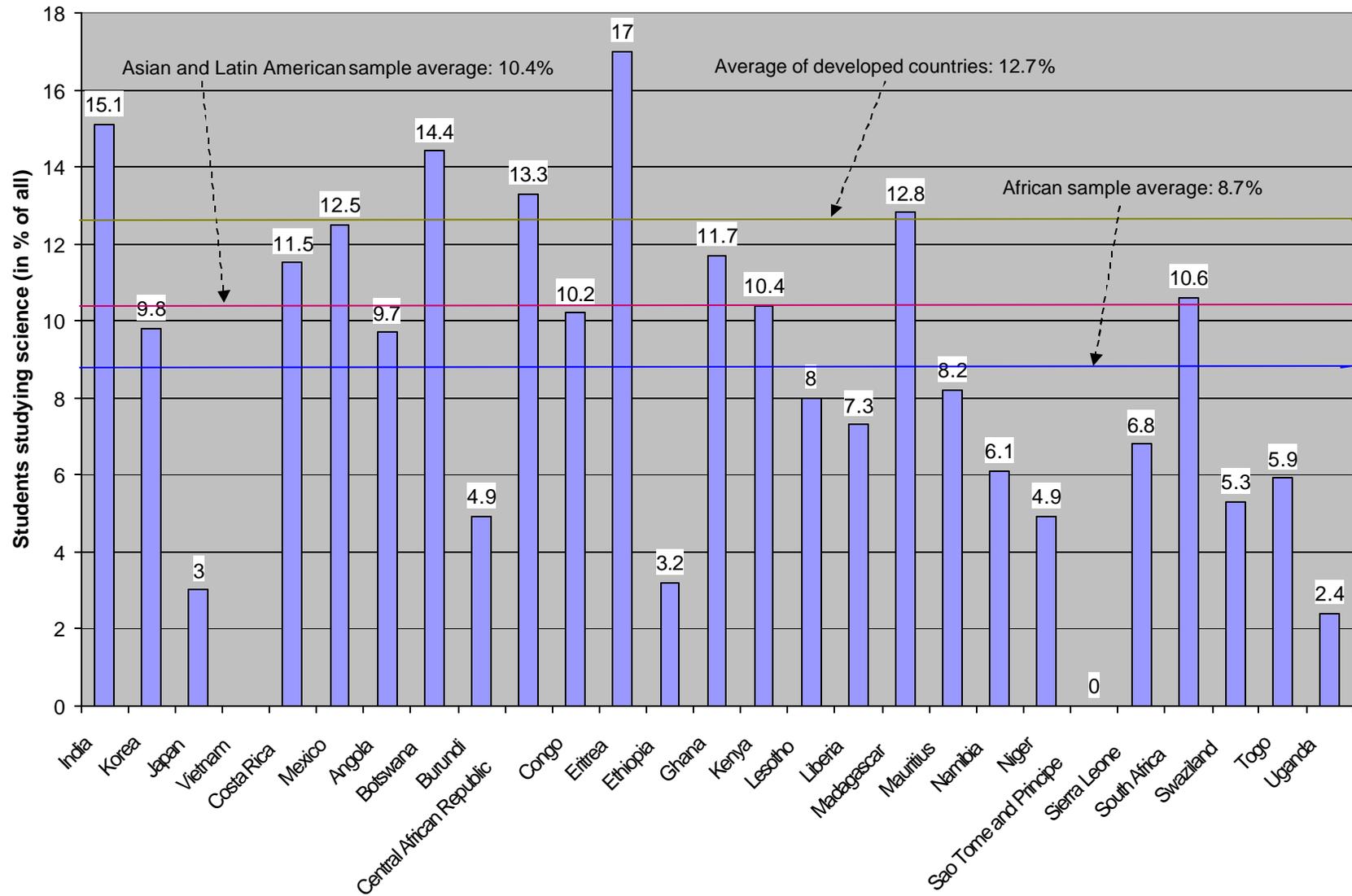


Figure 18. Students studying science (Source: UNESCO Analytical Survey [4])

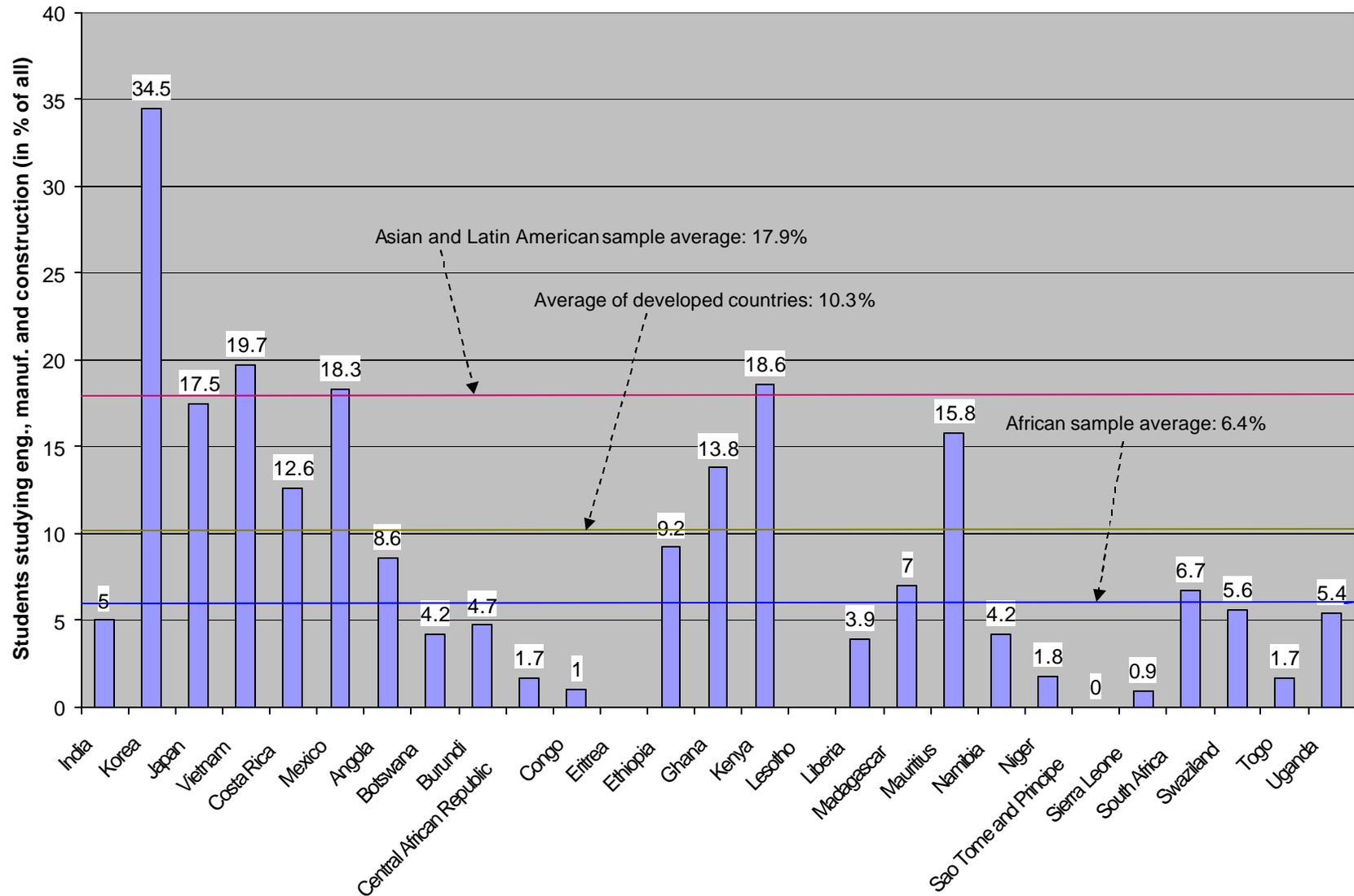


Figure 19. Students studying engineering, manufacture and construction (Source: UNESCO Analytical Survey [4])