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Thematic Study

Science and Technology and the Knowledge Society in Africa[1]

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GeSCI

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[1] The views expressed in this paper do not necessarily reflect the views of the UNECA.

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Introduction

Over the last five decades, the world has witnessed unprecedented changes that are largely driven by the rapid development and diffusion of scientific and technological breakthroughs. The rapid growth of communication and information technologies (ICTs) alone has shrunk distance and time between places and created new economic and social value. Similarly, developments in biotechnology have transformed the perception and understanding of life and generated endless applications in agriculture, environment, health and industry. As a result, the boundary between science and technology (S&T) has narrowed and what would have been considered earlier basic knowledge (or science) has acquired significant value. Some basic research outputs such as software, genetic sequences and nano-materials are of immediate economic value. This has driven many firms and institutions to increasingly invest resources not only in generating knowledge but in protecting and realizing commercial returns from their knowledge. The number of technology transfer offices established by research universities and institutions and private firms has grown rapidly.

Another direct measure of importance of knowledge could be seen from the number of applications public research universities have submitted to protect the knowledge they generate. For example, in the United States of America, the number of invention disclosures by universities that were filed with university technology management offices grew from 13,700 to 17,700 between 2003 and 2007 and the number of patent applications filed by reporting universities and colleges increased from about 7,200 to 11,000 between 2003 and 2007 (National Science Board, 2010). This is tremendous growth considering that in 1992, these universities were granted only about 1542 patents by the United States Patent and Trademark Office (USPTO). According to USPTO, most of the patents granted to universities are in the fields of chemistry, biotechnology and pharmaceuticals.

Universities are not the top patenting institutions. According to the USPTO, the top patenting institutions were IBM, Samsung Electronics and Microsoft that were granted 4,887, 3592 and 2929 patents, respectively, in 2009. Patenting activities are growing rapidly in developing countries as well. For example, China has been attracting increasing numbers of non-resident patent applications and has already overtaken the European and Japanese patent offices in the number of patents filed by non-residents. The non-resident patent applications filed with China's State Intellectual Property Office (SIPO) have increased by

about 140% between 2000 and 2004. The number of patents granted by SIPO to non-residents increased from about 32,600 to 44,142 between 2003 and 2006.

These developments have been key to the creation of the knowledge society whose socio-economic development is more dependent on and determined by knowledge rather than traditional factors of production such as capital, labour and land. This shift is not only visible through the number of publications, patents and dollar values attached to knowledge, but also in our social interactions and daily activities. For instance, remote service delivery, remote infrastructure management and remote maintenance are now a reality. A firm in India supports and manages the electronic transport and banking system in Europe without physically leaving India. Similarly, a South African TV firm manages its network of subscribers across the continent from one central base.

As has been the case with the countries mentioned above, there is growing recognition that Africa can only strengthen its economic performance by focussing on knowledge as a basis for economic transformation through considerable investments, creation, adaptation and utilisation of new knowledge (Juma, 2006). There is a growing universal recognition that science, technology and innovation (STI) play a significant role in a country's economic development and are key contributors to poverty reduction, health care, environmental conservation and development of the knowledge society, through their ability to solve problems and initiate and sustain economic growth. This is evidenced by the "Addis Ababa Declaration on Science and Technology and Scientific Research for Development", adopted by the African Heads of State and Government in January 2007. The leaders recognised that scientific and technical capabilities determine the ability to provide the basic necessities such as good health care, clean water, improved sanitation, adequate infrastructure etc., which calls for African countries to evaluate the role that science, technology and innovation play in economic transformation.

The main purpose of this study is to assess science and technology performance in Africa in order to determine whether the continent is on track in building a vibrant knowledge society. This will reveal to a greater extent if African countries are prepared to be future players in the global knowledge economy and if they are actively pursuing, accessing, acquiring, absorbing and upgrading new and emerging knowledge to build their scientific and technological bases. It also examines to what extent the role of S&T as a driver of

economic growth and development has been streamlined in the countries' development policies and plans in Africa, to create, advance and nurture the development of a vibrant knowledge society.

Knowledge is an important part of the economic activities due to its increasing speed in creation and dissemination and the increasing share of knowledge related activities in production, utilisation and trade. The knowledge society or economy is based on the creation, dissemination and utilization of knowledge, in which case knowledge assets are deliberately accorded more importance than capital and labour assets and the economy relies on knowledge as the key engine of economic growth. It is an economy in which knowledge is acquired, created, disseminated and applied to enhance economic development. The creation and dissemination of knowledge and technological innovations have been driven by advances in science combined with the information revolution (Dahlman, 2007). For the knowledge based development process to exist, there is need to have an educated and skilled labour force, a dense modern and intelligent information infrastructure (able to provide necessary services anytime anywhere), an efficient innovation system and an institutional regime that offers incentives for the efficient creation, dissemination and utilization of knowledge (Driouchi et al., 2006).

The next section examines the S&T development initiatives in Africa after which, section 3 explores how S&T relates to the development of the knowledge society and overall economic development. Section 4 explores the integration of the African continent into the global knowledge society by assessing to what extent African countries have mainstreamed S&T into the national development policies and plans in order to establish if policy makers are aware of the role S&T could play in a country's development. Section 5 reviews the status of African economies in terms of nurturing the foundations that could enable the transformation and development of knowledge societies. Section 6 dwells on the challenges to the emergence of a knowledge society in Africa and the last section presents conclusions and policy prescriptions for Africa.

S&T Development Initiatives in Africa

A number of S&T initiatives have taken place since independence of most African countries especially in the 1960s and 1970s. They pursued the development of S&T as a vehicle for achieving rapid economic development. During the 1970s many African countries established their national policy mechanisms for S&T, hence National Research Councils were established in many countries, to a greater extent as a result of the countries participation at the Conference of Cabinet Ministers responsible for the Application of Science and Technology (CASTAFRICA I) held in Dakar, Senegal in January 1974. Consequently, between the First Conference of African Ministers responsible for the application of S&T to development in 1974 and the Second meeting in 1987, African countries with S&T bodies grew from 4 to 28. R&D institutions specialising in natural sciences, agricultural, medical, nuclear, industrial and environmental research also grew rapidly on the continent. Almost all of these institutions were government-funded and were predominantly geared towards agricultural and primary products research (Adeboye T., 2000).

Several international organisations have played significant roles in the development of S&T policies in Africa. They have aided and supported the S&T development efforts through research studies in several countries, establishment of networks of multidisciplinary researchers, establishment of national institutions for S&T, studies on the transfer of technology from developed to developing countries etc. These organisations include UNESCO, UNCTAD, IDRC, the Swedish Agency for Research Co-operation with Developing Countries (SAREC) etc.

African governments have also taken strides in developing S&T in order to enhance S&T's contribution towards their socio-economic development. In most of the countries this was envisaged to be achieved through the development and application of S&T in order to improve the people's standards and quality of life. In April 1980, the Lagos Plan of Action for Economic Development (LPA) (1980-2000) stipulated visionary, far-reaching and unprecedented strategies on how to foster collective self-reliance and sustainable development on the continent. African countries agreed to pay attention to the role of S&T in integrated rural development, which required financial resources and political will to induce profound change with far-reaching effects on the use of S&T as the basis of socio-

economic development. Apart from the LPA, there was also the S&T Protocol of the African Economic Community (1994) which came up with certain actions to be taken by member States to ensure that S&T contributes to the solutions of the continents myriad problems. However, despite all these efforts, Africa remains the poorest with very few positive results from these initiatives. In 2005, the African Union Commission (AUC) and the New Partnership for Africa's Development (NEPAD) adopted Africa's Consolidated Science and Technology Plan of Action (CPA) 2006-2010, which articulates Africa's common objectives and commitment to collective actions to develop and use science and technology for the socio-economic transformation of the continent and its integration into the world economy. It is based on three interrelated pillars of capacity building, knowledge production and technological innovation contributing significantly to the development of the knowledge society on the continent.

The United Nations Economic Commission for Africa (UNECA) has also developed a number of programmes to assist member States to promote the use of science, technology and innovation (STI) to achieve sustainable socio-economic development. The STI programme offers policy research and analysis activities upon request by member States to meet their development needs and aspirations; outreach and advocacy activities through the bi-annual Science with Africa conference; STI support to AU/NEPAD; developed the Afro guide for the establishment of commonly accepted African and international standards for the promotion of ethics and good clinical ethics; and through the Access to Scientific Knowledge in Africa (ASKIA) which is an initiative to support and promote access to scientific knowledge by African scientists, decision makers, students and researchers. There are also several activities that fall within the African Innovation Centre initiative which are currently being developed in support of the development of business in Africa. In this regard UNECA has launched the following sub-programmes and activities: Africa Science to Business Challenge (ASBC) which offers opportunities for African entrepreneurs to learn how to transform their ideas into businesses; the African Science and Technology Endowment Fund (ASTIEF) which seeks to invest in bankable R&D outputs that are likely to make a commercial and social return to investment; and the African Technology Development and Transfer Network which supports training programmes, sharing of experiences and expertise and mentoring/coaching of emerging inventors and start-ups (UNECA/IST, 2010).

In the same vein, UNESCO has carried out a number of activities as part of the organisation's support to the African Union's Consolidated Plan of Action (CPA) with the aim of developing national STI policies for all those countries that have not yet developed their policies. This is being undertaken through studies assessing the status of African S&T policy formulation, the development of common African STI indicators, the creation of the African observatory of STI and through the creation of pilot science parks in Africa.

However, despite the development and implementation of most of the initiatives mentioned above, the results of studies reviewing the proxies related to the acquisition, adoption, dissemination and utilisation of new and emerging knowledge indicate that Africa has performed poorly in the past few years in relation to other regions of the world. This has to a greater extent been attributed to the fact that the main technological tasks in developing countries have merely been to acquire and learn how to use available technologies, and the only technological capabilities have been those for undertaking such routine investment and production activities (Bell and Albu, 1999). The continent has registered limited increase in R&D expenditures by foreign affiliates, attracted very few R&D projects and recorded the lowest growth in foreign patent applications and trademarks granted (UNECA/IST, 2010). Some studies have also noted that the number of scientific and technical journal publications has fallen but grown significantly in all the other regions (Hill, 2004, VTT, 2010[2]). From Table 1 below, it is observed that the selected African countries have relatively the lowest high-technology exports, with only South Africa performing relatively well in terms of scientific and technical journal articles as well as in trademark applications. While Singapore has the highest high-technology exports seconded by Malaysia, while China leads in both scientific and technical journal articles and trademark applications. Note that the countries were chosen on the basis of the level of per Capita GDP which is among the top 10 countries in the two regions (Africa and East Asia).

Table 1: Technological development proxies for selected African and East Asian countries.

	High-technology exports (% of manufactured	Scientific and technical journal articles	Trademark applications, total

[2] Presentation by VTT on the Dynamics of African Scientific and Technological Research, during the conference on Science, technology and innovations systems in Africa and Brazil, Hotel Arthur, Helsinki, Finland

	exports)					
Country	2005-2008	2000-2004	2005-2008	2000-2004	2005-2008	2000-2004
Botswana	0.5	0.4	59.0	59.2	757.5	-
Cape Verde	0.0	0.6	0.5	0.4	-	-
Mauritius	10.3	2.8	17.4	17.0	-	-
Namibia	6.2	2.6	19.4	16.7	1059.3	136.0
South Africa	6.0	5.8	2614.2	2272.9	29929.3	23033.0
Swaziland	0.1	0.4	2.8	3.6	1023.3	915.0
Korea, Rep.	32.6	32.1	17590.9	12193.8	133138.0	109803.4
China	29.8	23.9	49328.0	25299.1	687884.0	373186.6
Malaysia	49.9	58.1	715.6	498.4	24529.3	18072.2
Singapore	52.9	59.3	3747.2	2750.2	21195.5	17906.4

Source: World Bank

S&T and the Knowledge Society in the Literature

Knowledge has been at the heart of economic growth and development for some time. Despite the shift in recent years from the Information Society to an emerging global knowledge society, where emphasis is more on people's utilisation of knowledge rather than technology, it still remains a fact that information technology remains a central element of the knowledge society, combined with continuous learning particularly in S&T and innovation (Hafkin, 2008). The ability to generate new knowledge and new ideas that are then embodied in products and organisations has always served to fuel development (David and Foray, 2002). The foremost use of knowledge should be to empower and develop all sectors of society to understand and use knowledge to increase the quality of people's lives and promote social development. A socially inclusive knowledge society empowers all members of the society to create, receive, share and use information and knowledge for their economic, social, cultural and political development. In recent times, disparities in the productivity and growth of different countries have far less to do with the abundance or lack of natural resources than with the capacity to improve the quality of human capital and factors of production i.e. to create new knowledge and ideas and incorporate them into equipment and people's skills.

The key elements of the knowledge society are ICT use, highly educated and skilled people and progress in S&T and innovation (Hafkin, 2008). Scientific and technological knowledge not only engenders competitiveness in the global economy but also can improve the lives of the poor in many ways such as through better nutrition and health, higher crop yields, cleaner water, good sanitation and providing renewable energy sources. S&T tends to be central to the new sectors giving momentum to the upward growth of the whole economy reflected in the proliferation of jobs in the production, processing and transfer of knowledge and information, further improving the lives of people in a society. The accelerating speed of knowledge creation, dissemination, accumulation and utilisation has resulted in significant developments in S&T, giving rise to many new challenges to societies. The scenario puts more emphasis on the potential for exploring knowledge or the absorptive capacity (diffusion), the creation of new knowledge 9innovation), and complementary factors affecting the ability to exploit the potential entailed by knowledge independently of where it is created (Fagerberg and Verspagen, 2007; Cohen and Levinthal, 1990). This coupled with the role played by information technologies in the creation, acquisition and use of knowledge in human development and economic growth, has led to knowledge-based societies comprising of individuals striving to produce/generate, disseminate and utilise new knowledge to develop their economic and social activities hence becoming agents of change in their societies (David and Foray, 2002).

For S&T to contribute significantly to the development of knowledge societies, there is need to have a population with higher education and technological skills. These play a vital role in the development of S&T activities in any society. Apart from creating a conducive economic and institutional environment that will enhance knowledge diffusion, there is need to have people with a diverse range of skills by making more investments in education, skills development and life-long learning. Advanced skills and higher education play a complementary role to technological advances in this knowledge revolution. Theoretically, higher education allows workers to use existing physical capital more efficiently, it also drives the development and diffusion of new knowledge and technologies and also improves the capacity to imitate and adopt new knowledge and technologies which are the foundations for the development of the knowledge society. This implies that developing countries need to expand not only primary education, but also secondary and tertiary education in order to enhance the diffusion and utilization of knowledge for economic

development. Tertiary education and training is viewed with the regard to the crucial complementary role it plays in providing the basic technical abilities (over and beyond the abilities acquired at the primary and secondary levels) that are better predisposed for absorption and further development within productive activities (Wamae W., 2009).

Increasing higher education will lead to a rapid development and dissemination of knowledge, which will lead to more advances in technological innovation as it is becoming a more critical element for the countries' competitiveness. Firms need to be at least fast imitators and adopt, use and improve new technologies in order to remain competitive. Countries should develop capacities to acquire technological knowledge that already exists, be able to create relevant new knowledge and be able to disseminate and use the new knowledge throughout their economies. For all these processes to perform effectively and efficiently, there is need for intelligent, reliable and enabling information technologies. ICTs are a critical part of what enables the organization and coordination of global production networks and the integration of global supply chains (Dahlman, 2007). ICTs are a key enabler of business innovation and transformation and play a pivotal role in helping societies' economic sectors stay ahead and be globally competitive. To achieve this, societies should have a vision of where they want to be as regards the challenges ahead in terms of scientific and technological changes and the societies' priorities and needs. This calls for collaborative efforts with sectoral champions to enable the adoption of ICTs for greater productivity and economic benefits and for building an inclusive knowledge society, hence contributing significantly towards growth and development.

Advances in S&T have had significant contributions towards the health sector. S&T have led to improvements in human health through elimination of some diseases and reduction in the incidence of others through vaccines and greater access to clean water and sanitation. S&T has also led to the development of new sources of energy and higher levels of productivity. Improvements in knowledge acquisition and utilisation through S&T have been part of more general research concerning the impact of skills and human capital development on economic growth and poverty reduction (Nampota et al. 2002). However, the contribution of S&T to development and poverty reduction has not always been regarded as positive. For example, the HIV/AIDS pandemic for which S&T has not yet found a solution and in some instances developments in S&T have led to pollution, deforestation and

land degradation. Despite these challenges, S&T has had a significant positive contribution to people's lives in areas of food security, health, energy, clean water and sanitation.

S&T and the National Development Plans

In this section knowledge society is examined by taking into consideration the significance of S&T in the overall development plans and strategies pursued by African countries, in terms of education and skills development in the field of scientific and technological development, as well as the ability to convert R&D investments and technological knowledge into innovative products and services. Over the last decade the development policy agenda in many developing countries in Africa has been heavily dominated by the formulation and implementation of Poverty Reduction Strategy Papers (PRSPs). These policy documents have aimed at instilling greater poverty focus to these countries' developmental programmes by presenting a comprehensive package of policy initiatives in the various relevant spheres of government intervention. To a greater extent, they have been accompanied by comprehensive reforms in government budgeting, planning and financial management systems aimed at strengthening their mid-term policy frameworks and strategic policy tools for poverty reduction (Warren-Rodriguez, 2007). Recognising the role S&T plays in economic growth and poverty reduction, this section examines the extent to which S&T issues have been mainstreamed into the countries' development plans and policies. This is especially in terms of the general approach taken by the respective countries with regard to S&T considerations, the institutional settings promoting generation of local scientific and technological knowledge, the S&T content of educational and skills development policies and the inclusion of policy initiatives related to S&T dissemination in the spheres of infrastructure development and technology extension.

Despite recognising the significance of S&T development in economic development, growth and poverty reduction, one would expect issues of S&T to be priority areas in developing countries in Africa. However, this is not the case with a few countries that have been taken into consideration for this exercise. In this exercise we have looked at countries like Malawi, Zambia, Tanzania, Rwanda, Mozambique and Uganda. The study of these countries indicates that all the countries' development plans and strategies make reference to S&T development in various priority areas that comprise their poverty reduction strategies,

though with less emphasis with regard to science and general knowledge generation as compared to technological considerations. Most of the countries make reference to the significance of S&T for development limited to specific areas of policy intervention such as agriculture and ICT development. The PRSPs also tend to provide an extensive coverage of areas critical to S&T development such as education, technical and vocational education and training.

However, the issue of S&T as a priority area or as a crosscutting issue in the development arena is generally weak in the countries' policy documents. Among the countries included in this exercise only Zambia, Mozambique, Tanzania and Uganda, included science and/or technology as a policy priority. Zambia is putting more emphasis on science, technology, research and development for industrial development through the industries effectively adopting and adapting new technologies relevant to the Zambian economy. Uganda puts emphasis on agricultural research and technology development for the modernisation and commercialisation of the sector. Malawi and Mozambique include S&T as a crosscutting issue in their PRSPs. Only Tanzania, Rwanda and Mozambique explicitly focus on the development of science and scientific knowledge amongst their priorities.

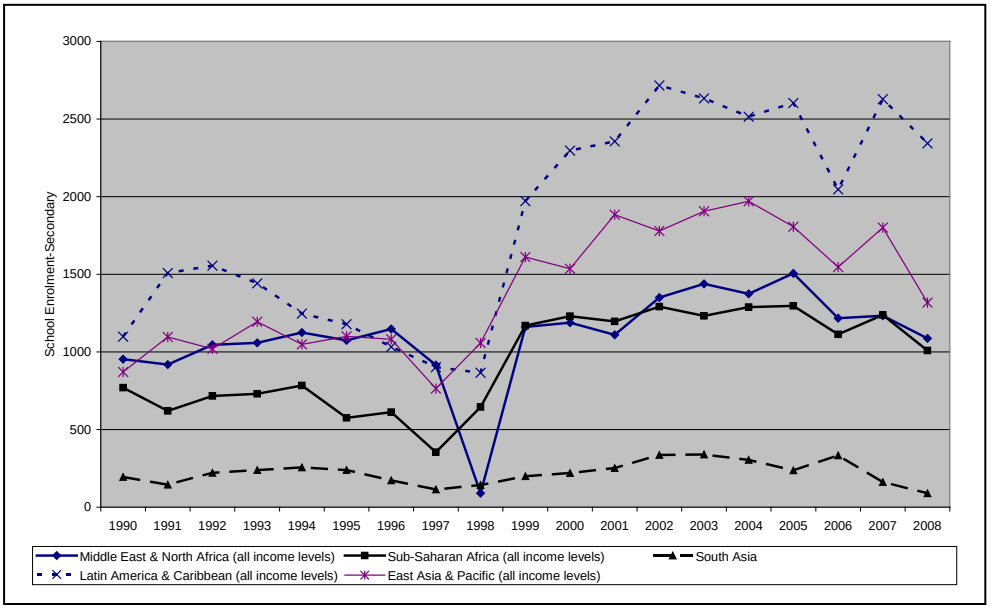
Among the policy documents reviewed, the Uganda PRSP presents a relatively comprehensive formulation of its strategy for the development of S&T, with a relatively detailed discussion on the impact of the returns to public expenditure on agricultural research and extension on income poverty, which were found to be higher than the expenditure on roads, education and health. It also explores the strategic priorities chosen as well as their economic, technological and policy implications in the provision of research and technological services incorporating socio-economic and poverty concerns (Uganda, 2004). The Zambian PRSP provides some details on how the country could adopt and adapt new technologies, public and private sector initiatives that aim to establish a viable local stock of scientific and technological knowledge, through the rehabilitation and strengthening of scientific and technological development institutions as well as through the provision of special tax and non-tax incentives to the private sector that fund the development of S&T (Zambia, 2002). Malawi's Growth and Development Strategy (MGDS) emphasises on developing a well developed, affordable and efficient information infrastructure and also developing, disseminating and promoting the utilisation of science, technology and research to improve productivity and quality of goods and services. This is

envisaged to lead to a well coordinated S&T generation, dissemination, effective and efficient operation of S&T institutions (Malawi Government, 2006). However, as is the case with most of the countries, the MGDS fails to incorporate the issues of S&T systematically in the various policy domains relevant for S&T development. In almost all the countries under consideration, S&T issues are presented in a more generic form, lacking a substantive analysis of existing S&T related economic and social conditions and their relationship to development and poverty status in these countries. They lack an in-depth analysis of the various policy options available and their likely implications for technology and development. Furthermore, although most of these countries had ICTs or science and technology policies in place, long before PRSPs, there are very few countries (e.g. Uganda) that make reference to the specific policy documents in the area of science, technology and R&D which mostly seek to promote the delivery of the goals and outcomes outlined in the policy documents. There is no clear and well articulated link between the countries sectoral policies and the overall government plans and strategies especially with reference to the S&T policies. Overall, this entails the general weakness in the formulation and implementation of national government plans and strategies, as other studies have also observed (Hewitt and Gillson, 2003; Warren-Rodriguez, 2007). This does not necessarily disqualify these documents from their role in science and technology development nor entail that key policy elements in these countries are not addressed in their national development plans and strategies; however, they provide generalised information on the lack of attention given to S&T issues in national development plans and policies.

Africa's Status in the Knowledge Economy

African countries have embarked on different policy initiatives which have had direct and indirect effects on the integration of these countries into the knowledge-based economy. This section examines the status of African countries as they transform themselves and integrate into the global knowledge economy in terms of human capacity development and the countries' ability to convert knowledge and innovation to economic growth and development. Education is the key element of a knowledge-based, innovation driven economy as it affects both the supply and demand for innovation (Dahlman, 2005).

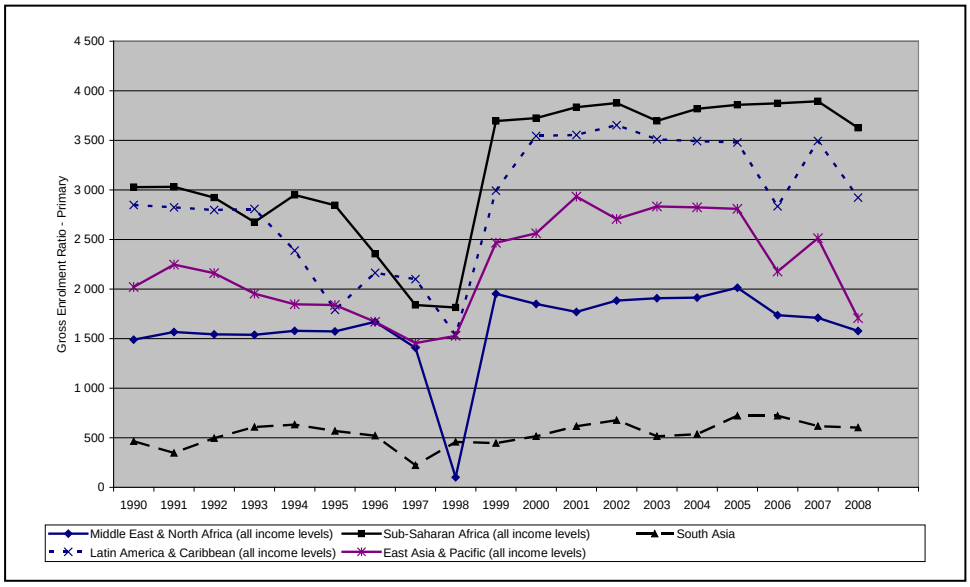
Figure 1.0: Gross Enrolment Ratio - Secondary



Source: World Bank

Human capital and skilled labour complement technological advances in this regard. New technologies cannot be adopted in production without a sufficiently educated and trained workforce. The demand side is also important since innovations may not take place in the absence of educated and therefore demanding customers and consumers. This calls for a critical look at the educational development trends in Africa in order to make sure emphasis is placed on educational levels and skills development that have a significant impact on knowledge and innovation as they contribute to the growth of these economies. This section therefore explores Africa's capabilities in terms of education and the continent's ability to acquire, adopt, disseminate and utilise knowledge and also transform or convert knowledge into growth and development outputs.

Figure 2.0: Gross Enrolment Ratio - Primary

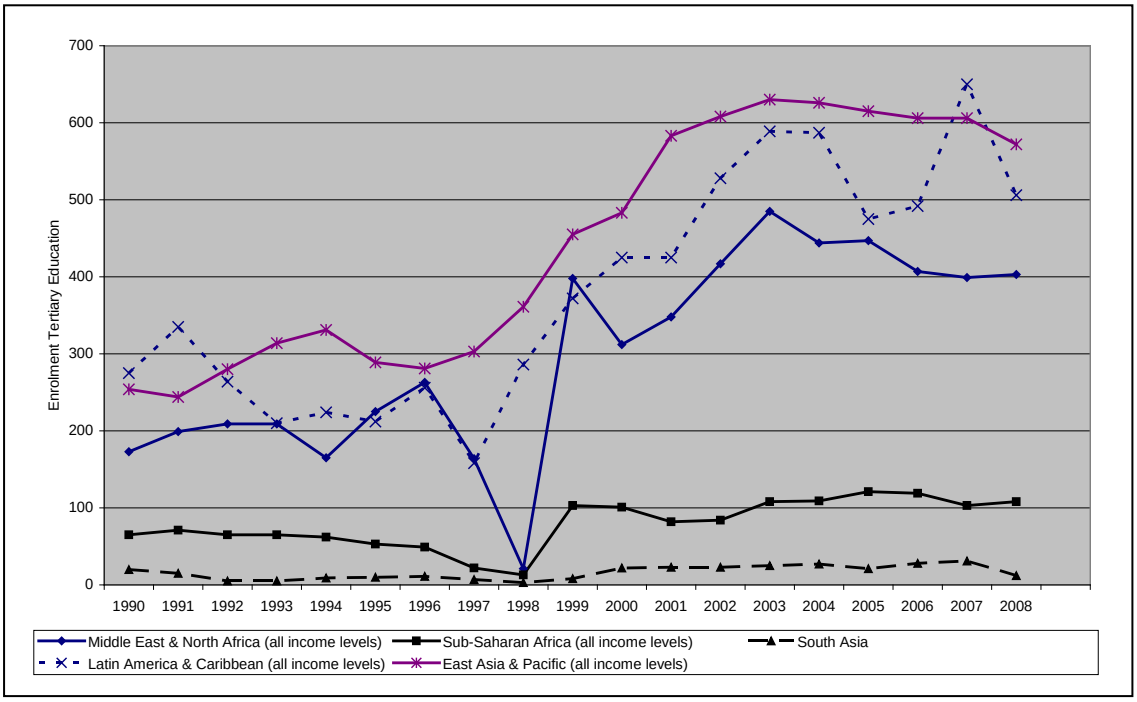


Source: World Bank

Figure 1.0 shows that Sub-Saharan Africa (SSA) and South Asia regions trail behind all the regions of the world on secondary school enrolment while Latin America and the Caribbean top the regions. The data reveals that the enrolment ratio dropped significantly in all the regions with SSA experiencing a decrease at an average rate of 3.05 percent between 2000 and 2008, while South Asia experienced a drop of 20 percent in the same period.

Interestingly, Figure 2.0 indicates that SSA leads all the groups in primary school enrolment. This buttresses to a greater extent the resolve by African governments' to promote primary education, as this increased at the average rate of 6.4 percent between 1990 and 1999, before decreasing at an average rate of 0.16 percent between 2000 and 2008, while surpassing all the regions involved.

Figure 3.0: Gross Enrolment Ratio – Tertiary Education



Source: World Bank

With reference to tertiary education, from Figure 3.0, it is observed that SSA and South Asia are again below the rest of the regions in terms of tertiary education enrolment, which is deemed critical for the development of the knowledge economy. According to the data from the World Bank (World Development Indicators, 2010), tertiary enrolment ratio grew at the average rate of 1.3 percent between 2000 and 2008 in SSA. However, in all the regions it is observed that decreases in enrolment in all the three education indicators were experienced after 2006. SSA also shows relatively the lowest levels in terms of the number of researchers in R&D per million people, though showing a drop in all the regions especially after 2006, as depicted by Figure 4.0.

Both the supply and quality of education and skill underpin the long-term ability of countries to assimilate and master new technologies. Education helps to increase the S&T absorptive capacity of a nation, enabling it to benefit from S&T inputs from a multitude of sources e.g. capital goods imports, licensing, spill-over effects of FDI etc. (Yusuf and Evenett, 2002). The society's absorptive capacity, partly determined by the availability of high-quality human capital, enables the assimilation and mastering of new production processes as well as enabling the society to innovate, hence contribute significantly to growth and development. Secondary education and particularly, tertiary education, are deemed critical in carrying out scientific and technological activities that are crucial for the development of the knowledge

society. This is supported by the country statistics in Table 2 below, which reveal that countries with higher enrolment in tertiary education are associated with higher levels of per capita GDP. Republic of Korea and Malaysia top the Asian group while in Mauritius leads the African group, while Swaziland has on average the lowest enrolment in tertiary education (2005-2008) and GDP per capita. Africa countries seem to be doing comparatively well in terms of primary and secondary education enrolment as compared to tertiary education, hence the low outcome in terms of technological outputs as stipulated below through Figures 4, 5, 6 and 7) as well as economic growth.

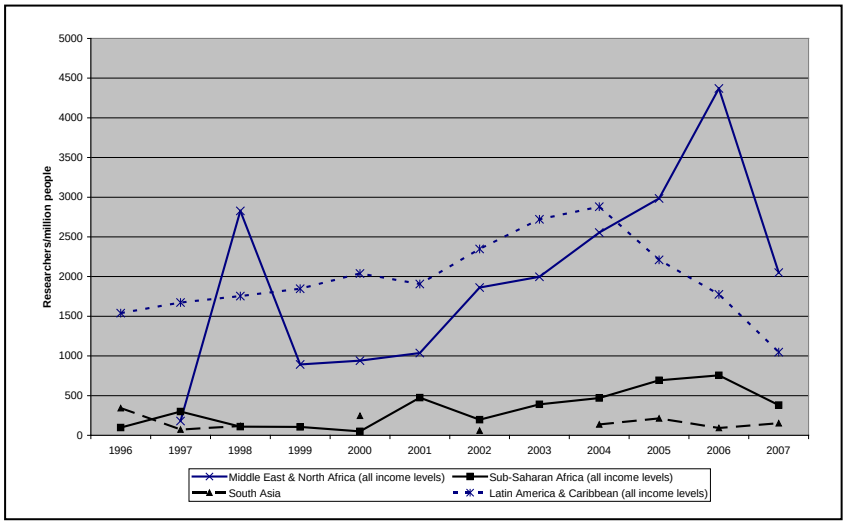
Table 2: Education attainment and Growth in selected African and East Asian Countries.

	Enrolment, primary (% gross)		School enrolment, secondary (% gross)		School enrolment, tertiary (% gross)		GDP per capita
Country Name	2000-2004	2005-2008	2000-2004	2005-2008	2000-2004	2005-2008	2009
Botswana	107.7	109.2	76.7	79.3	6.8	7.5	5,965
Cape Verde	116.0	105.4	67.1	-	3.5	9.4	3,064
Mauritius	101.3	98.4	80.4	88.2	16.1	23.0	6,742
Namibia	115.3	112.2	63.2	64.4	6.3	7.3	4,338
South Africa	106.4	104.5	88.2	94.1	-	-	5,798
Swaziland	94.2	104.9	42.1	49.7	4.6	4.5	2,479
Korea, Rep.	102.0	102.9	94.2	97.2	85.6	94.9	17,079
China	111.3	112.0	63.8	74.0	12.7	21.2	3,744
Malaysia	97.0	98.3	67.9	68.8	28.3	30.1	6,975

Source: World Bank

For African economies to remain competitive in the knowledge economy, their innovation systems should be able to convert these countries' R&D investments and their educational capacities into industrial and export strengths in the high technology sectors (Dahlman et al., 2005). This conversion could be illustrated through the number of patent applications, high technology's share in total exports and also through scientific and technical journal articles published.

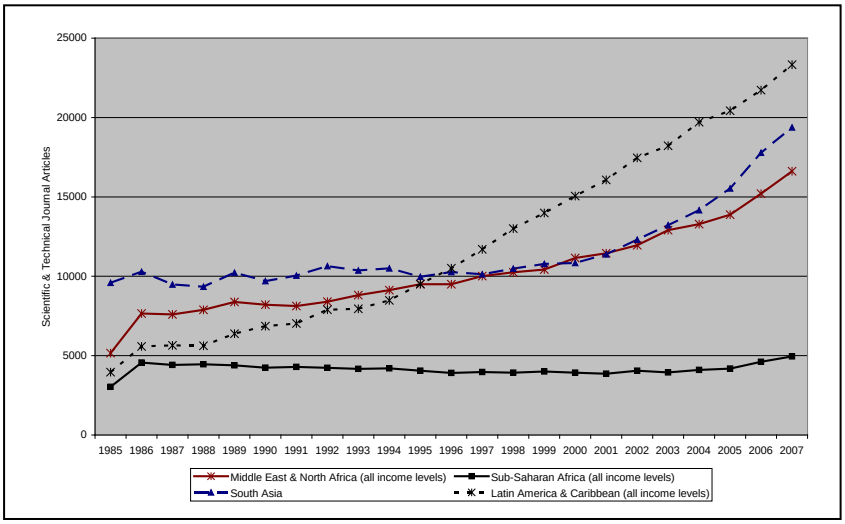
Figure 4.0: Number of Researchers in R&D per million people



Source: World Bank

With reference to SSA, Figure 5.0 shows that the region produced the lowest number of scientific and technical journal articles in relation to the other regions over the study period, with the rest of the regions showing significant increases in the number of scientific and technical journal publications. Relating Table 1 and Table 2, it is observed that countries with relatively higher enrolment rates in tertiary education have relatively higher high-technology exports, scientific and technical journal articles and trade mark applications as well as GDP per capita. For example, from Africa, Botwana and Mauritius have relatively higher enrolment rates in tertiary education which are associated with higher technological development proxies in Table 1, which is also true with the East Asian countries selected in the tables.

Figure 5.0: Scientific and Technical Journal Articles

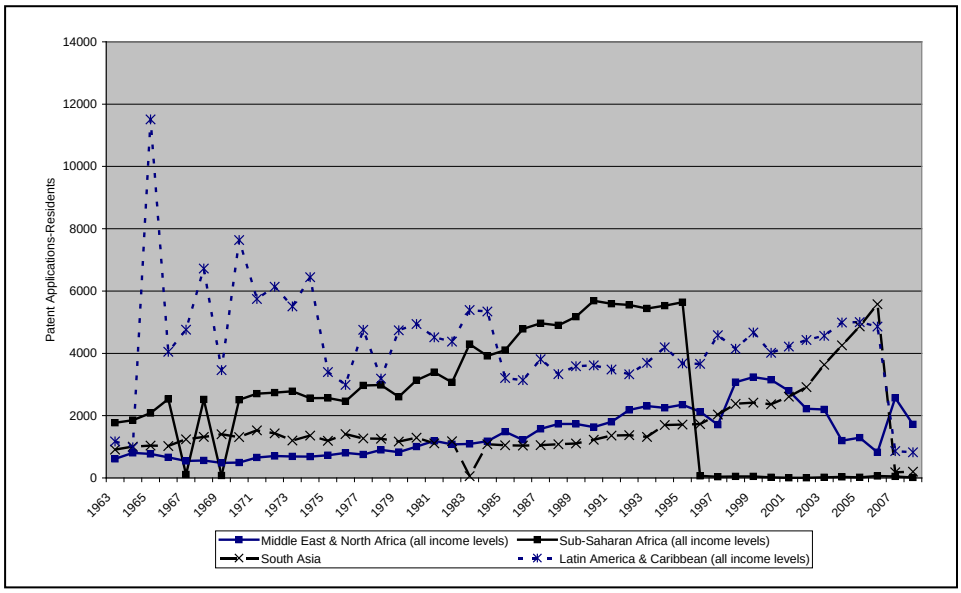


Source: World Bank

Figure 6.0 shows that SSA countries performed relatively better in terms of patent applications by African countries since the early 1970s before slumping significantly in the mid 1990s, after which the SSA countries have not been able to recover. Figure 7.0 reveals that in terms of high technology exports, the SSA countries, on average, have performed relatively better than the Middle East and North Africa and the South Asia regions. However, SSA's technological component in manufactured exports has not been able to surpass that of East Asia and the Pacific and Latin America and the Caribbean regions.

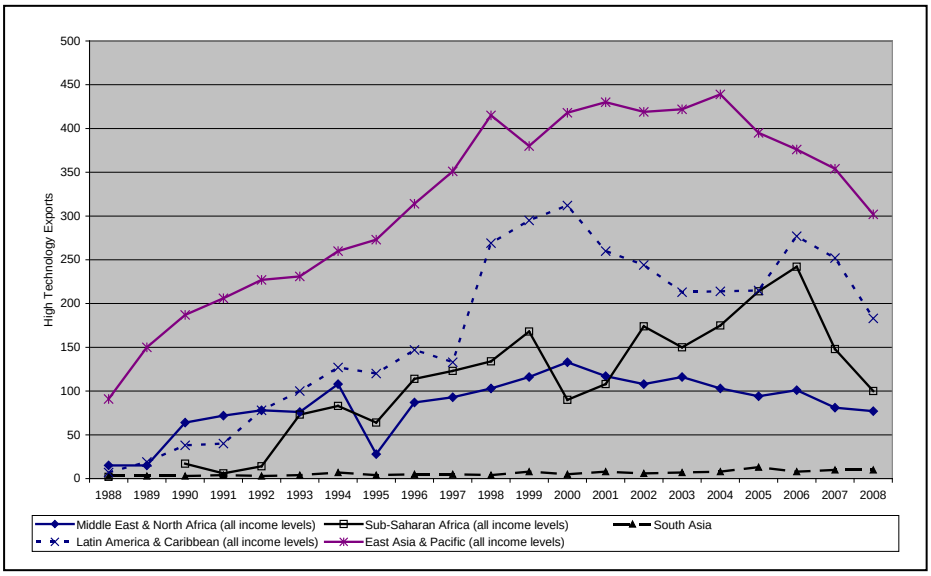
For countries to integrate into the knowledge economy they also require a modern and adequate information infrastructure which is aimed at facilitating effective communication, dissemination and processing of information and knowledge. ICTs play a significant role in the knowledge economies through the reduction of time, distance and transaction costs as well as the widening of the market base for the countries' products. The ability to store, share and analyse knowledge through networks and communities using ICTs allows economic agents to exploit the unique properties of knowledge to gain competitive advantage. Despite showing significant increases in mobile technology penetration in Africa, the region still rallies behind the East Asia and Latin America and the Caribbean regions in terms of ICTs penetration.

Figure 6.0: Trends in Patent Applications by Residents



Source: World Bank

Figure 7.0: High Technology Exports (% Manufactured Exports)



Source: World Bank

Challenges to the Emergence of a Knowledge Society

The main area of focus of the GeSCI's ALICT programme is to build the absorptive capacity of current and potential future African leaders to acquire, assimilate, transform and exploit the benefits of knowledge to produce a dynamic organizational capability through knowledge sharing and collaboration and exposure to technology. The contribution of S&T to the development of the knowledge society hinges on the proliferation of knowledge-intensive communities, which are characterized by strong knowledge production capabilities, ability to learn and exchange technological information and knowledge, as well as the intensive use of information technology (David and Foray, 2002). In this regard, higher education and skills development, especially with the growing awareness of the role of science, technology and innovation in economic development are deemed critical (Juma, 2006). GeSCI's ALICT programme goals and objectives are therefore well in line with the countries' development agenda with regard to the development of STI.

Recognizing this and also due to the decline of the educational system in the past decades, most African countries attempted to resurrect their educational systems by introducing free primary education. Given the lack of overall policy framework and an analysis of the resource implications involved, critics allege that the expansion of primary education has

been at the expense of quality (Riddel, 2003). For some countries such as Malawi, free primary education increased enrolment in the primary sector exerting pressure on secondary education which has led to the expansion of private and government secondary schools. However, a greater percentage of both private and public secondary schools are poorly or not even equipped with laboratories or basic equipment for science teaching, with a very low number of science teachers, raising challenges to the objectives and goals regarding the S&T policy for the country. The increased enrolment in both primary and secondary sectors exerts pressure also on universities as well as tertiary education as a whole, as people's expectations of access to continuing education increase (Nampota et al., 2008).

Higher education and research are increasingly being recognized as critical aspects to development in recent years, despite primary education being the focus in many African countries. Apart from providing education, higher education through universities and research institutions are at the centre of the development process in many countries, as is also the case with some colleges, research and technical institutes and polytechnic schools (Juma, 2002). Higher education and research institutions have therefore become a valuable resource for business, industry and society. However, most of the universities in Africa were originally designed to support nation building with the emphasis on humanities, hence facing challenges as the focus nowadays is on community building which has placed particular emphasis on building entrepreneurial skills among students so that they develop the capacity to transform ideas into business proposals as well as actual products and services for local and international markets (Juma, 2002). Hence leading to the lack of leadership skills in the long run for the championing of the role S&T could play in the development of the knowledge society.

Apart from market imperfections and strategic behaviours, the new trade theory has an impact on productivity and growth through its integration with the new growth theory (the endogenous growth theory), which is essentially based on market imperfections. In endogenous growth theory, the long-run growth rate can be improved by government policy to induce a higher saving rate and/or to incorporate externalities (Deraniyagala and Fine, 2001). Models linking trade and endogenous growth have examined issues of technological and knowledge spill-overs, and learning as the key mechanisms through which international trade and endogenous growth have been linked to productivity and economic growth

(Grossman and Helpman, 1991; Deraniyagala and Fine, 2001). This has been shown to be achieved through how international trade boosts a country's R&D sector by transmitting technological information, increasing competition and entrepreneurial effort and expanding the market size in which innovative firms operate.

It is also argued that imported capital goods embody information about new technologies and producers exposed to this information are seen as more likely to innovate, implying that increased amounts of resources will be devoted to R&D following trade openness. However, this is dependent on the absorptive capacity of countries, hence affecting both productivity and growth. Studies have shown that despite a much slower growth in imports of capital goods in other regions, this is not the case in Africa where imports of capital goods have actually grown rapidly since 2001 (UNECA, 2010). Africa is not a major producer of capital goods as its exports remained low and as in Figures 4-7, Africa has relatively low high-technology exports, the lowest number of researchers in R&D per million people, as well as the lowest number of scientific and technical journal articles compared to other regions. This could suggest the inability of the innovation systems in African countries to convert R&D investments as well as imported technologies through trade openness and foreign direct investment (FDI) inflows into significant innovative industrial and export products.

Many developing countries see global knowledge as a global good that they should access under preferential conditions as other trade issues. Many of today's developed countries did not respect the rights of those who owned technologies at the time. The ability of developing countries (especially in Africa) to grow depends on gaining access to and building on scientific and technological development of others. As such, the current global trade regime is seen by some as being inadequate in enabling African countries to build a knowledge society. However, as more and more countries become increasingly reliant on knowledge for their economic success and development, finding a proper balance between the needs of technology developers and users remains a challenge.

There are also a number of issues surrounding excessive ownership of knowledge and the numerous complaints about violation of knowledge ownership, especially patent rights. It is not clear whether strong intellectual property regimes and practices encourage generation of more and better (quality) knowledge, or patenting of research methods being a barrier to research freedom.

Similarly, science and technology takes place within a socio-cultural context. In this regard, several issues regarding public acceptance of the conduct of science and technology practices are important. Many of these involve ethical concerns and protection of people and their rights and protection of the environment. Some cultural and ethical beliefs may not be supportive of new and emerging sciences and application of existing technologies. For instance, there is a challenge to balance privacy of the individual and use of technology to prevent, solve and track crimes (e.g. video surveillance); and also between privacy and the need to provide accurate geographical information to the general public (e.g. Google maps)

The political system that underlies the attitude and associated policies of formal institutions in a country affects many aspects that are key to the emergence of the knowledge society in the country. In particular, governments in developing countries often play the deterministic role as an enabler or a barrier to technological knowledge transfer. Governments may decide not to adequately fund R&D, ban use of certain scientific and technological practices or impose high transaction costs of accessing technological knowledge (e.g. tax on R&D inputs), deployment and use of certain technologies (e.g. stem cell technologies). In addition, political instability, political interference in S&T especially in industry and political intolerance to scientific advancement etc. could have a major impact on S&T development and their role in a knowledge society. Studies have shown that political commitment to the development of S&T for development is a challenge. This is evidenced by the analysis of the synoptic review of the national development plans and strategy documents (PRSPs), which reveal that overall, the incorporation of S&T issues in PRSP is weak - signifying to a greater extent lack of knowledge by policy makers of the significance of S&T for economic growth and development.

While many African economies are performing well, there are fears that most of their growth is dependent on raw material exports and traditional primary sectors such as agriculture. For example, capital goods and high-technology products make up a very small proportion of many African economies. This somehow reflects the fact that the continent generates and acquires very limited amount of new knowledge. Many African countries are still struggling to tackle many diseases and poor sanitary and habitation that have largely been overcome in developed countries. On the positive side, the continent has a dynamic

and young population that is willing and eager to learn and open to seek opportunities and address their challenges. Africa has a fairly large pool of skilled scientists, engineers, technologists and technology based-entrepreneurs today with a better understanding of global trends than at any other time. Furthermore countries have recognized the importance of unleashing the creativity of individuals to determine their own future. There are indications that Africa has reached the technological and industrial stage that launched Asia's economic and social transformation. Since Africa does not carry a large stock of old technologies and industries, it could easily adopt and upgrade new and emerging knowledge to become a key player in the future. Despite all these developments, Africa still lags behind all the regions in terms of development. As such, a framework to assess the science and technology performance in African communities will be fundamental to determining whether the continent is on track in building a knowledge society, is prepared to be a future player in a global knowledge economy and is actively pursuing, accessing, acquiring, absorbing and upgrading new and emerging knowledge to build its scientific and technological base. The extent to which the key components are aligned to create, advance and nurture the development of a vibrant knowledge society has also to be addressed.

Recommendations and Policy Implications

The study has attempted to assess S&T performance in Africa in order to determine whether the continent is on track in building a knowledge society, or if is indeed prepared to be a future player in the global knowledge economy. This also includes an assessment of whether the continent is actively pursuing, accessing, acquiring, absorbing and upgrading new and emerging knowledge to build a scientific and technological base for the development of the knowledge society. The extent to which the role of S&T as a driver of economic growth and development has been streamlined in the countries' development policies and plans in Africa was also explored. The study recognises the significant role scientific and technological knowledge play in strengthening Africa's economic development. The region should therefore focus on this as a basis for economic transformation. It is important to emphasize that, for African countries to accelerate productivity in the knowledge economy, there is need to direct policy efforts towards restructuring economic incentives that encourage the acquisition, adaptation and utilization of knowledge into productive use, which would be achieved through expanded education and research and development, political leadership and support, creating awareness regarding the significance of S&T to

development, technological performance assessment and through the development and strengthening of the overall innovation systems in the different countries.

Political leadership: The development and effective utilisation of S&T is an essential issue that requires political commitment. The call for political commitment to the development of S&T is one of the key and persistent challenges facing the S&T sector. Political will and commitment plays a vital role in the streamlining or incorporation of S&T issues into the countries' national development plans and strategies. This entails the participation of high-level individuals such as cabinet ministers, parliamentarians and people in S&T committees/taskforces with enough knowledge on the role S&T plays in national development, with the core responsibility being that of promoting science and technology for development in the country.

Education: A solid knowledge economy cannot be built without education. However, it is not just the quantity of educated people that matters, but also the quality, field of specialization and its relevance and objectives. Education is at the core of developing a knowledge society especially through enhancing access, acquisition and utilization of technological knowledge. Education and technological skills enable people to create, share and utilize knowledge. The study reveals that the human resource capacity that exists on the continent does not have the required capability to utilize technological knowledge innovatively, efficiently and effectively so as to contribute significantly to economic growth and development. This calls for the need to expand access to educational levels that are critical for knowledge acquisition, creation, dissemination and utilization such as secondary education and particularly, tertiary education, which are deemed critical in carrying out activities that are crucial for the development of the knowledge society. There is also need to improve the quality of the whole educational system as well as content and relevance of what is taught. There is also need for a shift from the formal educational system to the development of life-long learning systems in order to keep pace with the speed in the generation and diffusion of knowledge and technologies. Deliberate initiatives should be designed to attract some of the best students to pursue a career in S&T field. For example, outreach programmes to raise awareness and spur interest in S&T as a career and provision of prestigious government scholarships and valuable private sector practical exposure. This will provide a

pool of future leaders who are conversant with the role of S&T to the development of the knowledge society.

Economic, legal and regulatory regimes: For African economies to be more productive in the knowledge economy, deliberate efforts to direct policies towards restructuring economic incentives that encourage the acquisition, adaptation and utilization of knowledge into productive use need to be pursued. This would entail the adaptation of the economic, legal and regulatory regimes to expand education and research and development through the development and strengthening of the countries' innovation systems. There is need to put more emphasis on government policies that encourage trade which facilitates knowledge spill over effects and transfer to African countries. This will enable African countries to increase productivity levels, enhance their international competitiveness and enter new markets and market segments for higher value added goods.

Public awareness, participation and acceptance: The general public's awareness, perception and acceptance of science and technology is not purely based on their level of knowledge but rather on understanding and values. There is need to assess the preparedness, awareness and acceptance level of a new or emerging science or technology. The weakness of the countries' S&T systems, the absence of institutional mechanisms for forecasting and identifying emerging issues and problems, with a view to realistically appraise social goals and societal needs to which S&T is expected to contribute; and the general low level of the countries' S&T awareness have all contributed to the weakening of the capacity of African countries to integrate S&T in their national development plans and strategies. There is therefore a dire need to raise awareness regarding the significance of S&T amongst policy makers, the public and institutions that play a significant role in the countries' development.

Traditional knowledge: Although often seen as being at loggerheads with modern science, traditional knowledge also forms a basis for the survival of many societies. In the areas of medicine, agriculture and construction, traditional knowledge remains a mainstay for millions of Africans and has been exploited globally. Current estimates suggest that the economic value of herbal medicines alone stands at over $60 billion. It is difficult to measure traditional knowledge- just like modern science- but there is need to assess to what extent and how traditional knowledge is accepted and could be integrated into S&T plans and strategies in order to meet future needs of the continent.

International dimension: This dimension constitutes a combination of international governance of science and technology, international alliances and collaborations in science and technology. As knowledge is increasingly generated through international networks, it will be key to assess the nature and characteristics of such alliances in contribution to S&T development of a knowledge society. A vibrant knowledge society is expected to have S&T institutions that collaborate domestically and globally and governments should play a leading or a strongly supportive role in a large proportion of these arrangements. This entails the establishment or strengthening of the countries' innovation systems in linking the government, the private sector, research institutions and academia.

Technological performance assessment: One of the major challenges being faced by African countries is the issue of the availability of data and statistics on the development of S&T on the continent. There is need to raise awareness and equip statistical institutions among African countries about the significance of S&T development and strengthen their capacities in the S&T field. The input and output measures or indicators for acquiring, generating and exporting knowledge, including those related to business, profession and technical services could be used to assess how well a country is progressing towards the knowledge society.

The above assessment could form a basis for identifying simple steps that countries can undertake to build vibrant, efficient and effective knowledge societies. Planned stakeholder and expert group meetings could refine the main areas of intervention. These main areas could be chosen based on the fact that interventions at this point are likely to have a multiplier effect or benefit on more than one development agent; a greater impact on the emergence of a vibrant knowledge society; are feasible within the political and legal, social and cultural, financial and technical capacity of the country or continent; and has the applicability of such interventions in the immediate future.

References

Adeboye, Titus (2000), “Science and Technology and Economic Policy Making in Africa: Individual and Institutional Linkages”, in Science and Technoloy Policy in Africa by Jeggan C. Sengor (Ed.), Africa World Press, Inc., Asmara, Eritrea.

AU/NEPAD (2005). Consolidated Science and Technology Plan of Action (CPA), 2006-2010. African Union Commission, Addis Ababa, Ethiopia.

Cohen, Wesley M. and Levinthal, Daniel A. (1999), “Absorptive Capacity: A new Perspective on Learning and Innovation”, *Administrative Science Quarterly, Vol. 35, No. 1,* pp. 128-152.

David Paul A. and Foray D (2002), “An Introduction to the Economy and the Knowledge Society”, *International Social Science Journal Vol. 171* pp. 1-23.

Dahlman Carl (2007), “The Challenge of the Knowledge Economy for Latin America”, *Globalisation, Competitiveness and Governability Journal*, vol (1) 1.

Deraniyagala, Sonali and B. Fine (2001), "Critical Review: New Trade Theory versus old Trade Policy: a continuing Enigma", *Cambridge Journal of Economics, Vol. 25,* pp 809-825.

Driouchi Ahmed, Azelmad El Mustapha and Anders G.C. (2006), “An Econometric Analysis of the Role of Knowledge in Economic Performance”, *Journal of Technology Transfer 31* pp. 241-255.

Fagerberg, Jan and Verspagen, Bart (2007, “Innovation Growth and Economic Development“, *International Journal of Technological Learning and Development, Vol. 1, No. 1*.

Government of Mozambique (2005), Action Plan for the Reduction of Absolute Poverty 2006-2009. Republic of Mozambique, Maputo.

Government of Rwanda (2002). Poverty Reduction Strategy Paper, Ministry of Finance and Economic Planning, Government of Rwanda.

Government of Tanzania (2005), National Strategy for Growth and Poverty Reduction. Vice President’s Office, United Republic of Tanzania.

Government of Uganda (2004), Poverty Eradication Action Plan (2004/4-2007/8). Ministry of Finance, Planning and Economic Development. Kampala, Uganda.

Government of Zambia (2002). Poverty Reduction Strategy Paper. Government of Zambia, Lusaka.

Grossman G.M. and Helpman E. (1991), Innovation and Growth in the Global Economy, the MIT Press, Cambridge, Massachusetts, London, England.

Hafkin Nancy (2008), Enabled Women in Knowledge Societies. Case study: The Philippines and Thailand, i4D, Massachusetts, USA.

Hill D.L. (2004), "Latin America Shows Rapid Rise in S&E Articles", Info Brief, NSF 04-336 August 2004 at http://www.nsf.gov.

Hewitt A and Gillson I (2003), "A Review of the Trade and Poverty Content in PRSPs and Loan-Related Documents". Overseas Development Institute (ODI), London.

Juma, Calestous (2006) "Reinventing growth: Science, Technology and Innovation in Africa", *International Journal of Technology and Globalisation, vol. 2*, Nos. ¾.

Malawi Government (2001), National Science and Technology Policy, National Research Council, Lilongwe, Malawi.

Malawi Government (2002), Malawi Poverty Reduction Strategy Paper. Government of Malawi, Lilongwe, Malawi.

Malawi Government (2006), Malawi Growth and Development Strategy (MGDS). Government of Malawi, Lilongwe.

Nampota D, Thompson J and Wikeley F. (2002), "The Development of Human Capacity in Malawi: The Role of Science and Technology". *International Review of Education (2009)* 55, pp. 59-74.

National Science Board (2010). Science and Engineering Indicators 2010. Arlington, VA: National Science Foundation (NSB 10-01).

Organisation of African Unity (1980). Lagos Plan of Action for the Economic Development of Africa (1980-2000). OAU, Addis Ababa, Ethiopia.

Riddell Abby (2003), "The Introduction of Free Primary Education in sub-Saharan Africa". Background paper prepared for the Education for All Global Monitoring Report 2003/4, 2004/ED/EFA/MRT/PI/62, UNESCO.

UNECA/IST (2010), A Technology Resurgence? Africa in the global flows of technology, UNECA Series of technology Transfer for Africa's Development, UNECA, Addis Ababa, Ethiopia.

Wamae, Watu (2009), "Enhancing the role of knowledge and innovation for development", *International Journal of Technology Management and Sustainable Development, Vol. 8, No. 3.*

Warren-Rodriguez Alex (2007), "Science and Technology and the PRSP Process: A Survey of Recent Country Experiences", School of Oriental and African Studies, Background Paper No.8.

Yusuf, Shahig and Evenett, Simon T. (2002), *Can East Asia Compete: Innovation for Global Markets.* World Bank, Washington D.C.