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Thematic study

Innovation and change and the knowledge society

Prepared for:

GeSCI

African Leadership in ICT Program

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Overview

This background note attempts to offer an overview of some of the key elements that may be needed to build an innovative knowledge society in Africa. The note first highlights the current status and the challenges that hinder innovation and the development of a knowledge society in Africa. It then proceeds to provide framework elements that could be considered by policy makers seeking to promote innovation in their countries. Each of the elements described includes a number of examples drawn from the experiences of countries inside and outside Africa. It then highlights measures that could be used to promote innovation in the education systems given its importance in the knowledge economy.

Introduction

The knowledge revolution has been driven by rapid development in areas such as information and communication technologies, biotechnologies, materials and nanotechnologies. These technologies have had a great impact on production and delivery of services to the society. In many ways, Africa was ill-prepared at the time when these technologies were developing rapidly. It is a fact that Africa still relies heavily on natural resources for their livelihood when the knowledge revolution has helped propel the rapid development of many other regions. Knowledge has now become a key asset that determines countries and firms' competitiveness in the global marketplace and their capabilities in delivering quality services to society. Building a knowledge-based society is a necessary but yet a far-fetched idea to many African countries which still struggle to tackle basic economic challenges. Nevertheless, Africa has made some strides in laying down some of the basic requirements and it needs to sustain and articulate these efforts.

The World Economic Forum's Global Competitiveness Index (GCI) highlights 12 pillars to assess a country's readiness to become and compete as a knowledge economy. These 12 pillars are: 1) institutions, 2) infrastructure, 3) macroeconomic environment, 4) health and primary education, 5) higher education and training, 6) good market efficiency and 7) labour market efficiency, 8) financial market efficiency, 9) technology readiness, 10) market size, 11) innovation and 12) business sophistication. Assessing Africa's current conditions upon these key pillars, one can say that the economic and business environments and primary education sector of many African countries have largely improved in the last two decades. Its market is also considered to have high potential and has witnessed rapid growth. Nevertheless, Africa still lags far behind in many areas. Its institutions, macroeconomic conditions and market efficiency are yet to be improved to benefit producers, exporters and investors in the knowledge-based fields. Africa continues to lack the basic infrastructure and not to say more advanced infrastructure and facilities that are essential to supporting a knowledge economy. The skills level of its people, technological sophistication and innovative capability of its institutions and firms remains low. Infrastructure, higher education and technology readiness are all important to fuelling innovation and facilitating changes.

For instance, infrastructure is fundamental to enabling and facilitating research and development (R&D) activities and hence innovation at individual, firm and institutional level. Unreliable power supply, backward water and sanitation systems, poor transportation networks and services and ineffective information and communication systems directly affect effective daily operation of research centres and firms, discourage investment in sophisticated and delicate equipment, divert resources from innovative activities to adaptive and mitigation measures (e.g. investment in standby electrical generators and boreholes) and hamper improvement in health and education.

A key way to speed up the development of Africa's basic and technological infrastructure and sophistication of domestic demand is through inward foreign domestic investment[1]. A recent study by UNECA has shown that the reason a number of Asian countries are becoming key players in technology development and ownership is partly driven by transnational corporations (TNCs) that have been attracted to their countries. These TNCs are now key investors in local R&D activities and create significant impact on driving host countries' innovation (UNECA, 2010).

In the last two decades, Africa has liberalized its economies and deregulated trade and investment regimes in a bid to create a favourable investment and business environment to attract foreign investment. As a result, Africa has witnessed a rapid growth in foreign direct investment (FDI). FDI inflows into Africa grew from about $9.7 billion in 2000 to about $87.6 billion in 2008 - almost 800%[2]. While a large proportion of the investment still concentrated on mining and petroleum industries, a diversified profile is observed in the last decade with increasingly FDI in financial and telecommunication industries and some investment in health, education and agriculture.

The influence of FDI on Africa's development towards a knowledge society is taking effect. For example, Africa's mobile phone revolution would have been much more muted without foreign investment and its associated benefits such as transfer of technology, management systems and business models. Similarly, the explosion expansion in higher education establishments in some of Africa's poorer economies would not have been possible without domestic and foreign investment. In countries such as Ethiopia, the number of privately owned universities has rivaled that of publicly funded universities. One can argue that some of the basic requirements of a knowledge economy are already present or emerging in Africa but more needs to be done. The paper highlights key challenges that Africa faces and recommends a few feasible and

[1] Belay Seyoum (2005) Determinants of levels of high technology exports an empirical investigation, *Advances in Competitiveness Research* , Annual,
[2] UNCTAD (2010) UNCTAD Handbook of Statistics 2010, TD/STAT.34, United Nations (New York and Geneva)

focal approaches that African countries can adopt to strengthen its foundation for building of a knowledge society.

1. Africa in the knowledge economy

A knowledge based society or economy, as used in this paper, refers to a society whose growth and development is based on continuous learning in which the stock of knowledge is continuously replenished and renewed. In such a society, extensive networks of and interactions among information sources and research actors ensures a continuous cycle of knowledge generation, acquisition, exchange and use. Innovation and change are spurred in this cycle and become a permanent feature of the society to drive economic growth and competitiveness.

According to the World Bank, the four pillar of a knowledge society include economic and institutional regimes, education and training, innovation system and information infrastructure. A quick glance at the ranking of countries by World Bank using two of its indices - the knowledge economic index (KEI) and the knowledge index (KI)[3] – shows that in most cases the KEI and KI scores do not seem to deviate from each other radically (see Table 1). Using a 10-point scale with 10 being the highest score, only South Africa and Mauritius have a score of above 5 in the KEI and/or KI scores. Regarding education and training, only 8 African countries considered here have a score of more than 2. As a whole, there are more African countries with a score of 3 or higher in economic incentive environments than in the other indices – innovation, education and information and communication technologies (ICT). The preliminary assessment indicates that much has to be put in place to improve all the four pillars of most African countries if they have to meet at least the basic requirements of a knowledge economy.

[3] KEI considers the economic incentive regime, innovation, education and training and ICT scores while KI considers innovation, education and training and ICT scores only.

Table 1: Assessing the knowledge economy in Africa

Country	KEI	KI	Economic[4]	Innovation	Education	ICT
DENMARK	9.52	9.49	9.61	9.49	9.78	9.21
Mauritius	5.48	4.63	8.01	3.63	4.03	6.23
South Africa	5.38	5.33	5.55	6.85	4.68	4.45
Tunisia	4.42	4.54	4.04	4.65	4.08	4.88
Namibia	4.28	3.37	7.01	3.14	2.65	4.34
Egypt	4.08	4.24	3.59	4.44	4.35	3.92
Botswana	3.88	3.37	5.38	4.06	2.65	3.41
Morocco	3.54	3.35	4.12	3.72	1.95	4.37
Algeria	3.22	3.57	2.18	3.59	3.66	3.46
Swaziland	2.78	2.87	2.51	4.17	1.97	2.45
Kenya	2.77	2.69	2.99	3.83	1.83	2.41
Senegal	2.57	2.16	3.79	2.85	1	2.63
Ghana	2.46	1.97	3.93	2.02	1.78	2.12
Mauritania	2.36	1.94	3.64	2.24	0.89	2.68
Uganda	2.36	1.76	4.18	2.33	1.18	1.76
Zimbabwe	2.25	2.96	0.12	3.55	2.38	2.94
Madagascar	2.21	1.47	4.45	2.11	1.11	1.18
Tanzania	2.17	1.54	4.05	2.1	1.17	1.36
Zambia	2.12	1.85	2.92	2.02	1.69	1.84
Mali	2.06	1.37	4.16	1.79	0.83	1.48
Lesotho	2.05	1.89	2.54	2.76	1.76	1.15
Benin	2.05	1.78	2.87	2.73	1.01	1.59
Angola	2	2.11	1.69	3.62	0.79	1.91
Nigeria	1.84	2.12	0.99	2.29	1.83	2.23

[4] Refers to Economic Incentive Regime

Sudan	1.78	2.22	0.48	1.86	1.28	3.52
Burkina Faso	1.71	1.09	3.58	1.78	0.31	1.18
Cameroon	1.71	1.91	1.12	2.65	1.38	1.68
Malawi	1.69	1.19	3.17	2	0.92	0.67
Cote d'Ivoire	1.65	1.75	1.37	2.28	1.09	1.87
Mozambique	1.58	1.08	3.06	1.67	0.3	1.27
Djibouti	1.47	1.3	1.99	1.68	0.88	1.32
Ethiopia	1.3	0.91	2.48	1.39	0.59	0.75
Eritrea	1.27	1.29	1.18	2.03	0.71	1.13
Rwanda	1.14	0.85	2.02	1.22	0.67	0.64
Guinea	1.07	1.22	0.62	1.51	1.09	1.05
Sierra Leone	0.96	0.87	1.22	1.47	0.58	0.55

Source: World Bank, 2009

NB: that KI considers only innovation, education and ICT scores while KEI include economic incentives regime scores in addition to those used in KI calculation

It is important to emphasize that the four pillars are not independent of each other but rather supportive of each other in creating a knowledge society. For instance, optimal economic incentive regimes are likely to encourage investment in research and development (R&D), technology acquisition and entrepreneurship through competition, intellectual property, investment, quality standards and procurement policies, among others. Similarly, ICTs could reduce the costs of doing business, facilitate information sharing, enhance collaboration and enable producers of products (goods and services) to penetrate previously unreachable markets. As such ICT is a facilitator (i.e. ICT facilitates innovation) as well as a beneficiary (i.e. innovation is needed to develop ICT-based products and processes). Higher education, in particular, is key in providing the skills and the creativity needed to develop ICT products and processes, undertake innovative activities and craft, assess and manage the economic incentive regimes.

While seen as pillar, they are more like subsets with significant areas of overlaps. For instance, learning and innovation takes place in the private and public sector. The pillars provide the necessary support and resources for investment in creation, dissemination and application of knowledge and skills. This cannot happen unless a country has a network of research centres, universities, think tanks, private enterprises and community groups that have the abilities and are equipped with supporting facilities to use both domestic and global knowledge bases. Furthermore, it is also necessary this knowledge is adapted to local needs in order to advance or create new knowledge.

Increasingly, global networks of firms and research institutions have become major vehicles by which countries and regions can build their knowledge economies. These include global production networks and global value chains as well as networks of R&D. Networks and alliances have become very important characteristics of a knowledge economy as they enable individuals, institutions and firms to gain access to knowledge bases of their partners worldwide, quickly learn the practices and skills needed to compete and penetrate markets abroad through others rather than rely on organic development.

The case of Seagate Technology Singapore - one of the major manufacturers of hard disk drives highlights this trend. Seagate has R&D and product sites in the United States, Ireland and Singapore and manufacturing facilities and customer services sites in the United States, Ireland, China, Malaysia, Singapore and Thailand. However, the Seagate Technology's facility located in Singapore is thought to be the only hard disk drive design and development centre of Seagate outside the United States and boasts of about 700 new inventions, 161 patents and 12 international product releases since 1982.

While this is a typical business model for many firms and institutions, the patents that are issued to Seagate in Singapore are, in theory, based on knowledge that has been generated in Singapore. As such it has built up the innovative capability of Singapore because the skills needed to successfully navigate from research and development to product launches have been acquired or learnt by the workers at this facility. A similar trend is being observed in South Africa where, through public-private-partnerships, the country has stimulated and promoted various partnering arrangements between its firms and foreign partners and between its research centres and foreign public and private entities of interest[5]. In general, Africa is still not well integrated in most of the global knowledge, industrial and technology networks.

2. Innovation in the knowledge society

Traditionally, innovation is seen as the process of combining resources in new or unusual ways to generate new or improved products (goods and services) and processes. These improvements or advances may range from slight improvements on existing ones to major leaps in performance and changes in technology systems and economic paradigms. For example, DSM (Netherlands) adopted a new biotechnology process from producing Cephalexin (antibiotic) that reduced the number of production steps from 10 to 4, improved the quality of the product, reduced waste and toxicity and increased market competitiveness of its product.[6] It is not just in the health sector. Today's smart mobile phones have more process power, application and user-friendly features than the computers of just a few decades ago.

These technological innovations will not be possible without significant investment in R&D and education, which generate basic scientific and technological knowledge upon

[5] Thorsteinsdóttir H., Melon, C.C, Ray, M., Chakkalackal, S., *et al* (2010) "South-South entrepreneurial collaboration in health biotech" *Nature Biotechnology*, Vol. 28, No. 5., pp. 407-416

[6] OECD (2001). The application of biotechnology to industrial sustainability, OECD: Paris

which innovations are based. For example, simple efforts to network computers by researchers gave birth to the Internet. Many of these efforts have become the basis of today's information technology firms such as Amazon, eBay, Google and Yahoo.

Innovations may also be non-technological. Non-technological innovations refer to new and improved ways of organizing internal business practices, external relations and market approaches. In simple terms, non-technological innovation can be viewed as changes in the way organizations undertake their activities. For example, the ability of customers to book tickets and hotels, access bank accounts and apply for entry visa over the Internet is enabled by new business models and practices that permit these activities to occur via virtual contacts in addition to or instead of physical presence.

These advancements are made possible with investment in knowledge generation, supportive policies that promote experimentation, market conditions that encourage the entry of new and innovative products, business methods and existence of an entrepreneurial culture that encourages the pursuit of new opportunities. Nowadays producers of products and processes have to continuously innovate in order to remain competitive. Innovation, therefore, must be regarded as a core objective of a knowledge economy and it demands sustainable efforts and investment.

3. Managing change in the innovative knowledge society

Innovation as described earlier entails changes in products, services, processes, practices and orientation. One of the characteristics of an innovation based society, therefore, is continuous change. However, change creates opportunities for some and presents challenges to others. Thus coping with change is essential to survival and development. In some cases, small changes do not necessarily present any major challenges (e.g. continuous change in computers over the last two decades) while major technological leaps or changes in economic paradigms may threaten livelihood of some members of society and render some skills and products almost irrelevant.

For example, the introduction of the electronic typewriters which were capable of storing and recalling tens of pages of materials on an in-built memory chip was a major technological leap of the 1970s. Today, the typewriter has but all been replaced by the computer. This has created brand new firms and industries while eliminating typewriter production and sales. One of the leading firms in this innovation was IBM which soon found itself behind new entrants such as Compaq and Dell.

Similarly, there has been a great shift from chemical and print-based imaging to digital-based imaging. This shift has revolutionized production, use and sales of non-digital cameras and reduced demand for chemicals, photographic papers and their associated skills. As a result, the shift has affected the entire value chain from investments in R&D to producers of camera and chemicals and owners of photographic studio that developed pictures. One fine example is Kodak's decision in 2009 to discontinue production of the famous Kodachrome film after 74 years on the market. Since the arrival of digital imaging, Kodak has been trying to catch-up.

The theory of creative-destruction suggests that new technologies may bring new products, services and firms to market while displacing and even eliminating some existing ones. Therefore, to remain competitive and relevant, firms, institutions and individuals have to continuously learn to build on their existing systems, acquire new knowledge and skills or risk becoming irrelevant. As such, managing change becomes critical in ensuring successful introduction of new ways of doing things and technologies, not only at firm level but at all levels. Managers, employees and the general population have to acquire the needed skills to enable them to be effective in the new environment.

There are at least four major components for change management: leadership (role modelling), skills (capacity building), a compelling story and promotion7. Leadership is key in mobilizing support, instilling trust and helping some members cope with change. . Leaders have to balance the costs and benefits of the change they wish to make happen with the risks associated with the new developments. For instance, countries where governments shifted from paper to electronic platforms in provision of services or were perceived to embrace ICTs, recorded significant adoption by its private sectors and citizens compared to those which did not. Countries such as Estonia, Korea, Mauritius, Tunisia and Rwanda are good examples of where leadership played a role in mobilizing support for ICT.

Capacity-building is critical in empowering members of the society at all levels with the necessary skills to remain relevant and useful in the new system. Such efforts should focus on the user and should be tailored to ensure society members could use, operate, manage and upgrade the new system. Such efforts should transcend “good intentions” and realistically inform workers and users of the critical elements they need to learn. Using the Information Technology (IT) example, many institutions continuously invest resources in training of their secretaries to acquire new skills that go beyond typing (enough for typewriters) as new software tools have many powerful application in preparing, editing, merging inserting and mass mailing etc. that were not possible with typewriters.

A compelling story is critical in forging a common understanding of the change that innovation often entails. Such a story could focus on aspects that motivate individuals to embrace change and learn new skills. While many of the original ideas may be drawn up from the top, the implementation, operationalization and management of new systems will rest at all levels. As such, it may be useful to ensure a sense of ownership in

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[7] Lawson, E. and Price, C. (2003) “The psychology of change management,” mckenseyquarterly.com.

designing, introducing and adopting new ways of doing things at all levels of the firm, institution and society.

Promotion is important to creating awareness and acceptance of change being introduced. The message should be clear and change is seen as being managed in a fair manner. In the 1990s, biotechnology was seen largely as a good tool for overcoming many of the challenges faced by poor countries, especially in agriculture. However, by the late 1990s and early 2000, agricultural biotechnology was seen largely as exploiting the poor through patents (seed control), dependence (e.g. use of herbicides needed to realize the benefits of herbicide-resistant crops) and bio-piracy. In conjunction with bio safety fears, agricultural biotechnology has not lived up to expectations as opposing groups were engaged in fierce debates while Africa remained held hostage to the competing camps.

While incentives may be used, it is perhaps useful to highlight that they are generally bad because they encourage individuals to undertake decisions they would otherwise not take; on the other hand, incentives may be claimed by individuals and institutions that would have taken the decision anyway without the incentive, In both ways, effects of incentives tends to be short-lived. For example, annual bonuses that come almost standard do not serve as true incentives since individuals expect to get the bonus every year. Similarly, some of the most generous incentives awarded to foreign investors have not been as effective as increased international demand and prices for commodities in attracting foreign direct investment.

Therefore, if incentives are to be used at all, they should be targeted and be understood as temporary means with time-specific effects. There are many reasons why individuals, institutions, firms and societies may decided not to embrace change. Some of the common ones include, the fear of losing power with change (e.g. privatization shifts power from government to private sector), lack of understanding (e.g. biotechnology as unsafe), a focus on challenges as opposed to current strengths one can build on, loss of identity and attachment to the current system, lack of confidence in leadership to manage the change and cultural beliefs among others.

In recent times, the Internet was seen as threatening to the profitability of existing telecommunication firms and electronic voting (e-voting) is still perceived as unreliable in many African countries. All these seem irrational given that up to 90 percent of the population in some of Africa's poorest populations did not have access to modern telephone services. Similarly, countries that have embraced mobile banking seem to find mobile or e-voting too risky while visualising the transportation of ballot papers unsecured by canoes as an acceptable risk.

If Africa has to build a knowledge society, parallel efforts must be put in building the capacity of leaders to manage change. The entire society needs to be mobilized and the skills of many of those to be affected have to be upgraded to secure their future. Efforts to understand the real reasons for resisting change may be useful in finding common ground, forging a common understanding and future and promoting ownership of the need to change

4. Some of the key challenges in the innovation value chain

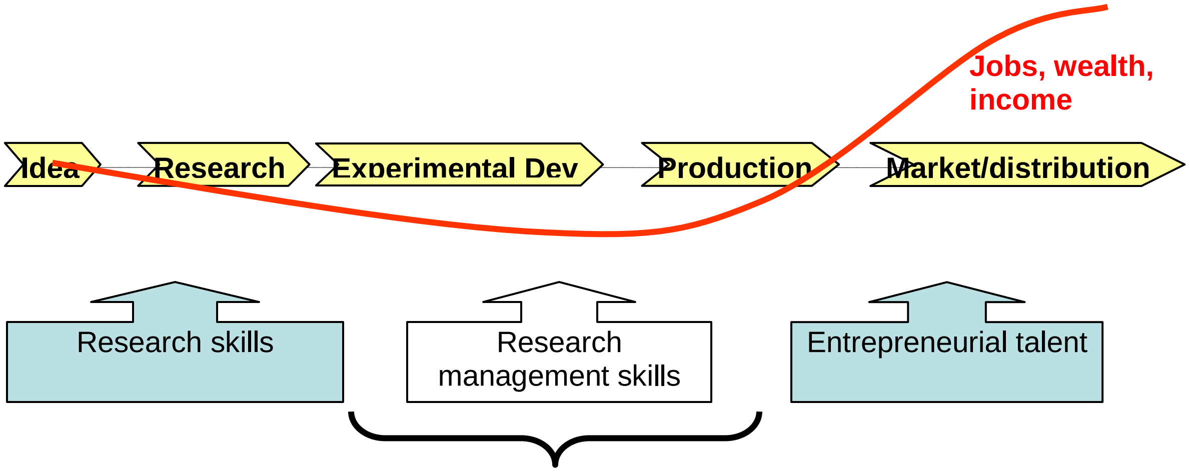
In order to apply new ideas and knowledge to tackle development challenges, knowledge needs to be created first. For this reason, investment in science and technology is fundamental to generating ideas that stimulate or drive innovation. In a traditional linear model, research is undertaken to generate outputs that may provide leads for further investigation or go to field trials and pilot stages. Promising marketable leads (e.g. services, processes, methods and products) are then further refined to meet market needs as shown in Figure 1 below. In practice, there are loops between the various stages, leaps of stages, backward and forward movement of ideas and potential failures at any stage. For example, research may be needed to improve the production or marketing of a product. Similarly a promising research product or service may go straight to market (e.g. acquired or spin-off), may fail late-stage trials (e.g. drugs, vaccines and plant varieties) or fail to compete in the market place.

At each of these stages, a number of support institutions and performers are needed. In general, ideas are generated by researchers, entrepreneurs, institutions, industry, market and general public, among others. In order to test the ideas, research is traditionally performed by researchers with the support of their institutions, firms and other players (e.g. funders of research). Investment is needed to generate ideas. In Africa, most of the research is funded by institutions, governments and external donors.

In some technology fields, experimental development is the most expensive stage of R&D activities as work moves from laboratory desks to the field (e.g. clinical and field trials of drugs and crops, respectively). At this stage, Africa faces three main challenges: 1) most donors and governments do not traditionally fund work at this stage, 2) the skills needed to navigate complex regulatory requirements and generate the data that are crucial to registering and protecting the products are in many cases missing, rare or still emerging and 3) some of the key institutions needed to oversee or approve these stages are either missing, ill-equipped or poorly managed. Therefore, there is a significant financing, knowledge and institutional gaps that have to be filled in.

For example, one survey suggests that it is much easier to register a new drug developed outside the Southern Africa Development Community (SADC) countries than to get approval of one that is manufactured domestically. Such institutional weaknesses discourage innovation and investment in the local pharmaceutical sector but indirectly promote trade or import of finished products.

Figure 1. Summary of major stages moving from ideas to market and associated skills



Source: Konde V (2004)

The social and/or economic value of knowledge and innovation is realized at the stage when the products or processes go to market. It is at this stage that jobs and wealth are likely to be generated. In Africa, the major hurdles at this stage include a lack of seed and early stage capital to bring the product to market and the skills needed to nurture the start-ups to become commercially viable firms. It must be borne in mind that most investors do not necessarily invest in the products only, but they take into consideration the ability of the management team to bring the product(s) successfully to the market.

Existing data suggests that Africa lacks or is still developing some of the key institutions needed to promote innovation, invests little resources in S&T and lacks clear leadership that appreciates and promotes creativity, innovation and entrepreneurship (UNECA, 2010)[8]. Very few African countries have identified some of these key challenges and designed measures to address them.

5. A framework for building an innovative knowledge society in Africa?

5.1 Human capital development

As stated earlier, human capital is needed not only to undertake R&D but also to navigate complex regulatory requirements and to successfully nurture and manage start-ups. In particular, Africa needs R&D managers capable of identifying potentially useful and marketable research. In a way, countries need to develop not only science and engineering talents but also technology entrepreneurs and S&T managers to ensure a complete and effective innovation value chain from idea generation to research output commercialization. The availability of experienced S&T managers helps ensure

[8] UNECA (2010) A technological resurgence? Africa in the global flows of technology, UNECA series on technology transfer for Africa's development, United Nations (New York and Geneva).

that the limited human, financial and institutional resources are efficiently mobilized and allocated and potentially useful research outputs are well-protected and exploited to obtain their full potential benefits.

For instance, Africa accounts for about 2.4% of the global researchers – slightly higher than the number of researchers in India. Yet, India was granted three times more patents than Africa, by the United States Patent Office in 2008. More importantly, India is an established information technology powerhouse with software exports in excess of US$48 billion. While it is difficult to make conclusions on such scanty information, it however begs the question on the efficiency of Africa's innovation system and entrepreneurship.

In the United States, it was observed that many of the technology clusters are in regions with most of critical skills needed to develop the industry. For example, the biotechnology clusters of California and New England (Boston area) have generated a number of biotechnology firms due to the high concentration of top life research universities and are rich in qualified and experienced scientists, managers and service providers that have been involved in the development of biotechnology firms over the last three decades (Konde, 2009)[9]. There success seems to partly lie in the presence of human capital with the necessary skills to undertake and manage research groups as well as entrepreneurial talent to bring research outputs to market.

5.2 STI infrastructure

Both hard and soft STI infrastructure is critical in filling in the financial and knowledge gaps mentioned above. Soft infrastructure, such as networks and information technology could provide access to management, intellectual and R&D resources as well

[9] Konde, V. (2009) Secrets to developing a successful biotechnology industry: lessons from developing countries, *Asian Biotechnology and Development Review*, 11, 11-33.

as key information on sources of knowledge, market opportunities and potential partners across national borders.

Hard infrastructure, such as well-equipped centres, science and technology parks, technology and business incubators, among other common facilities, could reduce the costs for innovator and entrepreneurs in the process of taking research products and new products to market, increase cross fertilization of knowledge, improve chances of being funded and encourage entrepreneurship. In a way, the development scope of STI infrastructure should not be limited to laboratories in universities and R&D centres.

One area where infrastructure has been catalytic in empowering innovation and entrepreneurship is information and communication technology (ICT). Following the liberalization of the telecommunication sectors in many African countries, private investors have built the basic telecommunications infrastructure. This ushered in a mobile phone revolution in Africa. The number of subscribers increased by 585% between 2003 and 2009[10], the number of innovative products have continued to multiply (e.g. mobile banking and government) and numerous entrepreneurial opportunities have been created. All these innovations and developments that have transformed and empowered many lives in Africa would not exist without investment in ICT infrastructure.

5.3 Innovation financing

There are several ways of increasing innovation financing. The most direct one will be to offer special grants, loans and guarantees for start-ups and new firms as well as subsidies and tax incentives for R&D. Governments could extend these facilities to innovative individuals, start-ups and existing firms to encourage them to bring their products to market. For example, São Paulo State Research Support Foundation

[10] UNECA (2009) M-banking - An African financial revolution? United Nations (New York and Geneva)

(FAPESP) of Brazil is entitled to 1% of all the taxes collected in the State of Sao Paulo - Brazil's richest State. In return FAPESP is required not to spend more than 5% on administration and the rest must be invested in scientific and technological development[11]. In addition, incentives may also be provided to individuals and venture capital firms that invest in innovative start-ups and those private operators that establish incubators and S&T parks.

Governments could encourage foreign firms to invest in laboratories, train and sponsor local students and work with national institutions to bring desired products, services and processes to market. For example, Illovo's Zambia Sugar and the National Institute for Scientific and Industrial Research (NISIR) partnered to bring vitamin-A fortified sugar to the market. The main objective was to reduce vitamin-A deficiency in the country. Similarly, foreign automotive manufacturers in South Africa teamed up with South African Bureau of Standards (SABS) and engineering faculties of some of the leading universities to establish the Euro Type Test Centre in South Africa, one of the world's leading testing centres for engines and catalytic converters. The centre is invaluable to exporters of automotive products to countries where international emission testing is a legal requirement.

5.4 Academia-industry-government cooperation

In Africa, the private sector is still relatively small and is largely not technologically sophisticated (e.g. SMEs). However, promoting cooperation through joint projects and programmes of mutual interest to R&D centres and SMEs/large firms could stimulate generation of research ideas and products/services that are demand-driven. Over time, such cooperation will demonstrate the importance of R&D, especially to SMEs and encourage joint funding and implementation of projects. This relationship would also

[11] UNCTAD (2004) Biotechnology Promise: Capacity-building for Participation of Developing Countries in the Bioeconomy, UNCTAD/ITE/IPC/2004/2.

develop a private sector that can influence training and research agenda of technical colleges, universities and R&D centres and fuel investment in R&D and technology acquisition, enabling African firms to become competitive.

Governments could also require ministries to reserve a fraction of their budget for promoting STI joint initiatives between their R&D centres and SMEs. For example, United States agencies with external budgets for (R&D) in excess of $100 million per year are required to set aside 2.5% of that budget for contracts with small businesses and those with external budgets for R&D that exceed $1 billion per year are required to set aside 0.3% of that budget for cooperative research between small businesses and a federal laboratory or a non-profit laboratory under the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programmes, respectively[12].

5.5 Legal and regulatory framework

An effective legal and regulatory framework that encourages fair competition, promotes innovative firms, attract foreign innovative investors and remove administrative entry barriers must be put in place. The World Bank's Doing Business survey tracks countries on a number of these legal and regulatory requirements such as ease of paying taxes, registering and closing a firm and getting finance. Although the score have gone up in general, most African countries continue to fare poorly (see www.doingbusiness.org for details). In addition, countries may also need to develop clear technology commercialization rules, including ownership of intellectual property rights on products of publicly funded research. In general, the main goal is to reduce the costs of innovation and entrepreneurship related activities to the individual and the business in a country.

[12] For details, see http://www.sbir.gov/

5.6 Promotion of technology innovators and entrepreneurs

In recent times, technology entrepreneurs such as Bill Gates, Steve Jobs and Mo Ibrahim have become celebrities with the same standing as film stars and accomplished footballers. African scientists continue to play a key role in developing the seeds that feed the continent and offer complex but lifesaving medical procedures under difficult conditions. STI promotion has to include exhibition, promotion of technology entrepreneurs, appreciation and recognition of technological achievements and the many career and business opportunities that S&T offers. Promotion could help attract students, especially girls, to pursue sciences and science careers, individuals to invest their time in science and technology development, and conduct research. It is also important to gain public support for S&T. African countries should aim to produce the next generation of Bill Gates and Mo Ibrahims.

5.7 International collaboration

International collaborations enable and facilitate knowledge acquisition and learning. R&D collaboration, in particular, may help domestic institutions and firms to access and operate in multidisciplinary fields such as information technology and biotechnology. Partnering arrangements could fill domestic knowledge and R&D funding gaps, share the costs and risks of R&D products development and provide access to research facilities and natural, technological and human resources beyond national borders. African S&T diplomacy has to be stepped up as very few African countries have formal R&D or S&T technology agreements with leading and emerging technology producers (e.g. the United States, Germany, Korea and Sweden). For example, Kenya seeks to establish an S&T unit in Boston (United States) while Egypt and South Africa have several S&T agreements with developed countries.

6. Encouraging innovation in the education system

6.1 Innovation in higher education

There is a general agreement that the education system, particularly higher education system, increasingly plays a critical role in the innovation system of a country. Some of the key trends that have driven this belief include the increasing collaboration between the private sector and research universities, increasing protection of knowledge generated in universities (e.g. patent applications and grants), changing mandates of research universities and commercialization of university knowledge.

The performance of a research university is no longer measured just in terms of courses offered, research undertaken and numbers of students graduated or size of faculty. Instead, universities are increasingly competing in terms of patent applications and patents granted, papers published in top journals, number of licensee issues and start-ups or spin-offs seeded. It has been observed that the mandates of educational institutions have increasingly taken on board the need to perform research and development (R&D) activities and entrepreneurship[13].

These research universities are now commonly referred to as “entrepreneurial universities”. According to Burton, entrepreneurial universities are supposed to possess at least five main characteristics: [14]

1. independent, strong and efficient managerial systems;
2. interdepartmental cooperation and increased collaboration with the outside;
3. wider funding resource base;

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[13] Etzkowitz, H. and De Mello, J.M.C (2000) The endless transition: relations among social, economic and scientific development in a triple helix of university-industry-government relations, Rio 2000 Triple Helix III Conference.

[14] Burton, R.C. (1998) Creating Entrepreneurial Universities Organization Pathways of Transformation. IAU Press

4. stimulated and strengthened academic research units; and
5. Integrated entrepreneurial culture throughout the university.

These characteristics are seen as essential to enabling universities to function as centres for enterprise formation, facilitators of knowledge diffusion and transfer and agents for development (creating jobs and wealth). The university, in this case, provides sufficient 'space' to enable research teams to operate as 'quasi-firms'[15], encourages enterprising individuals to work closely with their clients (industry and government) and supports or rewards entrepreneurship.

In general, the university undertakes these activities through common goals and projects with the industry and the government. These goals and projects serve as vehicles for promoting such partnerships. For example, it has been observed for a long time that academia-industry-government partnerships in Canada, the Republic of Korea and United States are well established. In 2006 alone, the United States Federal Government R&D support to industry and universities was about $20.9 billion and $30.1 billion, respectively. At the same time, industry supported R&D expenditure in United States universities stood at $2.4 billion. It indirectly shows the presence of university-industry-government relations in R&D projects[16].

There is a growing volume of evidence of the increasingly important role that universities play in promoting innovation and entrepreneurship through partnerships, even though these relations are still not well characterized in Africa. Several countries have already considered ways of encouraging such partnerships. For instance, South Africa's Innovation Hub (The Hub) is strategically located between two of the country's

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[15] Many research teams already exist as "semi-private enterprises" that identify opportunities and seek the resources needed to realize them. Often they have a credible research management team, invest in emerging fields of interest and compete for contracts and grants from private and public institution - just like private consultancy firms (see Etzkowitz, 2003).

[16] For details and break down, see the National Science Foundation Science and Engineering Indicators 2007

premier scientific and industrial research institutions: the University of Pretoria and the Council for Scientific and Industrial Research (CSIR). Its location promotes the flow of knowledge between The Hub's tenant (industry) and the centres of knowledge generation (academia). Similarly, Egypt's Mubarak City for Scientific Research and Technology Applications (MuCSAT) is located in an industrial area housing about 40% of the Egyptian industry. Established in 1993, MuCSAT comprises 12 research centres and occupies 250 acres. Its location is deliberately designed to encourage collaboration with industry.

In some least developed countries, such as Rwanda and Ethiopia, universities are one of the places with a critical mass of skilled and highly qualified individuals. Universities in developing countries may have to work closely with governments and donors to turn an idea or technology into a firm or at least develop it to a level where it is mature enough to be applied directly by its industries, given the levels of industrial sophistication. The model could also be applied in low-technology fields.

The Earth University, Costa Rica, has developed a unique curriculum for teaching entrepreneurship termed the Entrepreneurial Projects Programme. This is a permanent course which is designed to: train students to become entrepreneurs with an understanding of the economic, social and environmental aspects of a firm; promote the creation of economically profitable, ecologically viable and socially acceptable food production enterprises; and develop value added businesses in the agricultural food system. The main goal of the programme is to develop in the students the entrepreneurial mentality and leadership and management skills needed to run an agricultural firm in developing countries. The students develop business ideas and must identify a member of staff to act as a technical advisor during the three years of the programme (Larsen, 2003).[17]

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[17] Larsen, T. (2003). Member Empowerment and Enterprise Development Programme: Appraisal Report, Noragric Report No. 18, Agricultural University of Norway

The student and the technical advisor work together as partners and go through the various stages of business development. However, decisions must be made independently by the student. Key decisions include identification of the business ideas, undertaking feasibility studies, environmental assessment, seeking investment and launching the business. The University acts as a bank and provides $3,000 as working capital and charges market interest rate on the loan. The student produces, markets and sells the product. He/she is required to provide monthly financial reports and meets all the administrative costs. The business is then finalized and liquidated, all the bills paid and the investment recovered with interest. The Earth University - the promoter of this initiative - is applying this model to meet some of the development challenges in other regions, including Africa.

Another unique model for encouraging innovation in universities is SIFE[18] (Students In Free Enterprise) - an international non-profit organization – that brings together business and university managers to mobilize and encourage students to use their skills to contribute to the development of their communities. In the process the students acquire skills to become successful and socially responsible entrepreneurs. In brief, participating students form groups and develop community outreach projects using basic business concepts. Furthermore, SIFE management teams also offer participating students exchange and placement opportunities in industry.

For example, a SIFE student group at University of Zimbabwe embarked on a project to assist a group of widows and single mothers producing detergents, polishes and waxes, among others. The women's firm suffered from inconsistency in their product quality, poor book-keeping and lack of a business strategy. The SIFE team undertook a needs assessment, helped the women register the firm, secured a loan to purchase equipment and developed business strategy for the firm. As a result, profits soared 500% and the struggling informal establishment has a bank account.[19]

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[18] (http://www.sife.org)

[19] See Project Clean-up at http://www.sife.org/ProjectStories/media/africa/pdfProjectCleanUp.pdf

There are numerous examples of universities encouraging innovation in order to initiate change in society. Whatever the case may be, the underlying message is that the university must provide an environment in which such activities could be undertaken. The sophistication of the university does not necessarily encourage or hinder innovation and entrepreneurship.

6.2 Innovation in primary and secondary schools

Although it is not expected that practical solutions will emerge from primary and secondary school students, it is important to impart the key mindset and skills needed to become innovators and entrepreneurs. In Zambia, a national competition is organized each year for secondary school students to develop new and innovative prototypes in all areas of technology and fields of life. Dubbed the Junior Engineers, Technicians and Scientists (JETS) competition, students compete first at the school level, the district level, at the provisional level and finally at the national level. Since 1988, JETS has also been implemented in Nigeria.

Such competitions cultivate in students enquiry and problem-solving skills and encourage them to address real life challenges by learning and trying how to combine or manipulate existing knowledge, resources and materials in unusual ways. It also encourages students to see Science and Technology as a useful career of choice. It is perhaps important to also remember that many students in primary and secondary schools will enter universities and workplaces. Therefore, imparting the right mindset and skills they need to retain and develop their creativity and become innovative earlier in education is very important.

One way of achieving this goal at a national scale is to encourage governments to work closely with the private sector in designing skills development and training programmes and integrate them into normal curriculum. Areas of interest could include industrial visits and arrangements of industrial leaders and practitioners to participate in field projects of students and deliver lectures and seminars in specific topics of interest such as architecture and industrial design, health and pharmaceuticals.

It is also possible to include in the normal curriculum a period to enable students to participate in 'work-life' as a compulsory requirement. This model is commonly used in Nordic countries. Alternatively, students can take a compulsory year off school to participate in development and work-related activities as is the case in Ireland.

Yet another approach that is commonly used in teaching students practical skills is "clubs". Although science clubs exist, clubs that are designed to teach students problem solving skills are not common. These could include clubs that focus on applied science that are not generally taught in secondary and primary schools, such as mechanical and electrical engineering, designing and information technology. Such clubs could make learning of science and technology a pleasant and practical experience and cultivate curiosity and problem-solving skills that are critical in encouraging innovation.

Conclusion

For many African countries, the knowledge economy is still a far-fetched idea but the central argument in this paper is that African countries can develop their innovative knowledge economies. As already shown, Africa has made significant strides in building some of the basic foundations of an innovative knowledge society. In most of the assessments, African countries are performing relatively better in terms of macroeconomic, market and financial environments. Although they are not among the best, the scores have increased drastically. These could encourage innovation in the private sector.

However, Africa is performing poorly in terms of higher education, infrastructure technology readiness, market-size and innovations. In particular, innovation infrastructure has remained underdeveloped or is just emerging. The lack of supportive innovation infrastructure and the limited higher education facilities underpin the lack of a critical mass of researchers, research managers and technology entrepreneurs.

Based on the foregoing, African countries could use a number of the elements described earlier to build a knowledge society. All the recommendations take into consideration the fact that many African countries do not have vast human and financial resources. They could all be integrated and applied through a comprehensive science, technology and innovation policy and strategy.

Such a national science and technology policy should not focus on the activities and institutions that lie within the responsible ministry of science and technology. As already shown, innovation cuts across all ministries, private entities and all communities and cannot be confined to one or a few ministries. Instead the policy should seek the involvement of all line ministries and agencies, and mobilize the private sector, academia and donors.

Secondly, the strategy should seek to build skills through formal and informal education. It is important to provide the necessary support to develop skills for the knowledge society. Primary education is no longer sufficient to enable majority of the individuals to effectively participate in an innovation based knowledge society. Lifelong learning, informal training and attachments could be used to quickly build skills and knowledge.

Thirdly, and more importantly, the policies and strategies should be designed to attain a clearly defined future. The future will not be exactly as was defined. However, policies and strategies that are designed to address today's challenges are unlikely to meet the needs of tomorrow. This remains a major challenge as there are almost no efforts to make technology forecasts. For instance, network computing is expected to grow into a major market by 2014. To what extent are policy makers in Africa preparing to participate in this revolution or will our data be stored in developed countries?

Fourthly, there is a need to build the capacity of African policy makers to effectively manage change. If Africa has to build a knowledge society, parallel efforts must be put in building the capacity of leaders to manage the opportunities and challenges that change and innovation entails. The entire society needs to be mobilized and the skills of many of those to be affected have to be upgraded to secure their future. In particular, special effort is required to be put in place measures to help some members of society to cope with change.

Finally, innovation brings significant levels of uncertainty to many firms, institutions and societies. African policy makers will have to discern their own benefits and risks of innovation and change from those of others in order to make informed decisions as well as plan their development strategies. This could be achieved by developing the capacity of leaders to understand the real reasons why some of their development partners may be resistant change. This is vital in enabling African policy maker to sell their own vision of the future to their partners in developed and developing countries.